A SCM APPROACH TO PROJECT MANAGEMNET IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

by

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Declaration of Originality

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Date: *December 2015*

Abstract

The two factors that motivated this research were, the failure of construction projects to adhere to budget and schedule and the lack of insight into the management of complex construction projects in South Africa.

The construction industry world-wide repeatedly faces challenges in managing projects, this study attempts to solve this problem by investigating an alternative approach to PMBOK project management. This study comprised of five main objectives.

The first objective was to identify factors that cause budget overruns and schedule delays in the construction industry; while the second was to identify *Supply Chain Management* (SCM) methodologies applicable to project management in the construction industry.

The third objective was to attempt to highlight the similarities that exist between manufacturing and construction and determine if a manufacturing approach to construction will improve the management of construction projects. The manufacturing industry implements structured frameworks such as the *Supply Chain Operation Reference* (SCOR) model that facilitate effective management of complex tasks.

The fourth objective of this research was to evaluate project management effectiveness and assess whether a SCM approach to project management, more specifically, whether a structured framework such as the SCOR model can be directly implemented in a construction project to facilitate improved management processes. In order to evaluate such an approach, it was necessary to obtain input from practitioners working and managing such projects. As such, a series of discussions and interviews, as well as a case study were conducted at a prominent multinational company, referred to as *Company A*. Furthermore, consultation of industry experts from manufacturing, construction and engineering consulting was conducted in order to evaluate the feasibility of SCM as a substitute or supplement to conventional PMBOK project management.

The principal findings of the research indicate that a structured framework will improve management processes of construction projects, however, the SCOR model specifically is not industry specific enough to be directly applied to the construction industry. Furthermore, there exists specific complexities within the construction industry and more specifically, in the South African construction industry that limit the effectiveness of SCM initiatives such as SCOR. Such complexities include but are not limited to; skills shortages, habituated and familiar management techniques, BBBEE, labour unions, strikes, a politically unstable economy and a change in the socio-economic drivers which motivate human resources.

A SCM approach to project management in large corporations was deemed impractical. Instead, a simplification of conventional PMBOK principles and processes by means of a hybrid management

model, incorporating SCM as a supplement to PMBOK, was deemed feasible in Small and Medium Enterprises in South Africa.

The fifth objective of the study was to determine which project metrics should be measured and managed to improve project management of construction projects. A list of proposed “construction project metrics” that are specific to the success of South African construction projects is presented.

Key project management practices and skills considered important in successfully managing a construction project were found to be; effective communication, contractor appointment procedure, resourced schedule development, appointment of dedicated project planner and scheduler, as well as personnel management and development.

Opsomming

Die twee faktore wat hierdie navorsing gemotiveer het, is die mislukking van konstruksieprojekte om te hou by die begroting en skedule; en die gebrek aan insig in die bestuur van komplekse konstruksieprojekte in Suid-Afrika.

Die konstruksiebedryf wêreldwyd staar herhaaldelik uitdagings in die gesig, wat betref die bestuur van projekte; hierdie studie poog om hierdie probleem op te los deur 'n alternatiewe benadering tot PMBOK ("Project Management Body of Knowledge")-projekbestuur te ondersoek. Hierdie studie het vyf hoofdoelwitte bevat.

Die eerste doelwit was om faktore te identifiseer wat begrotingsoorskrydings en skedulevertragings in die konstruksiebedryf veroorsaak; en die tweede doelwit was om voorsieningskettingbestuur (VKB)-metodologieë wat van toepassing is op projekbestuur in die konstruksiebedryf, te identifiseer.

Die derde doelwit was om te poog om die ooreenkomste wat tussen vervaardiging en konstruksie bestaan, te beklemtoon, en te bepaal of 'n produksiebenadering tot konstruksie die bestuur van konstruksieprojekte sal verbeter. Die vervaardigingsbedryf implementeer gestruktureerde raamwerke soos die SCOR-model *("Supply Chain Operations Reference* model"), wat effektiewe bestuur van komplekse take fasiliteer.

Die vierde doelwit van hierdie navorsing was om projekbestuursdoeltreffendheid te evalueer, en te bepaal of 'n voorsieningskettingbestuursbenadering tot projekbestuur, en meer spesifiek, of 'n gestruktureerde raamwerk soos die SCOR-model, direk in 'n konstruksieprojek geïmplementeer kan word om verbeterde bestuursprosesse te fasiliteer. Ten einde so 'n benadering te evalueer, was dit nodig was om insette van praktisyns te verkry wat met sulke projekte werk, en bestuur. As sodanig, is 'n reeks gesprekke en onderhoude, sowel as 'n gevallestudie uitgevoer by 'n prominente multinasionale maatskappy, verwys na as *Maatskappy A.* Verder is raadpleging van raadgewende kundiges in die bedryf van vervaardiging, konstruksie en ingenieurswese gedoen, om die haalbaarheid van voorsieningskettingbestuur as 'n plaasvervanger of tot aanvulling van konvensionele PMBOK-projekbestuur, te evalueer.

Die hoofbevindinge van die navorsing dui daarop dat 'n gestruktureerde raamwerk die bestuursprosesse van konstruksieprojekte sal verbeter, maar die SCOR-model spesifiek is nie industrie-spesifiek genoeg om direk toegepas te kan word op die konstruksiebedryf nie. Verder bestaan daar spesifieke kompleksiteite binne die konstruksiebedryf en meer spesifiek, in die Suid-Afrikaanse konstruksiebedryf, wat die effektiwiteit van voorsieningskettingbestuursinisiatiewe soos SCOR, beperk. Sulke kompleksiteite sluit in, maar is nie beperk tot; vaardigheidstekorte, gewoontevormde- en aanvaarde bestuurstegnieke, BBBEE, vakbonde, stakings, 'n polities-onstabiele ekonomie en 'n verandering in die sosio-ekonomiese drywers wat menslike hulpbronne motiveer.

‘n Voorsieningskettingbestuursbenadering tot projekbestuur in groot korporasies word as onprakties beskou. In plaas daarvan, 'n vereenvoudiging van konvensionele PMBOK-beginsels en prosesse, deur middel van 'n hibriede-bestuursmodel, waarin voorsieningskettingbestuur as 'n aanvulling tot PMBOK geïnkorporeer word, is as haalbaar geag in klein-en medium ondernemings in Suid-Afrika.

Die vyfde doel van die studie was om te bepaal watter projekmaatstaf getalle gemeet en bestuur moet word, om die projekbestuur van konstruksieprojekte te verbeter. 'n Lys van voorgestelde "konstruksieprojekmaatstawwe" wat spesifiek is tot die sukses van Suid-Afrikaanse konstruksieprojekte, word aangebied.

Sleutel projekbestuurspraktyke- en vaardighede wat as belangrik beskou word om 'n konstruksieprojek suksesvol te bestuur, is vasgestel as; effektiewe kommunikasie, kontrakteur aanstellingsprosedure, ten-volle-toegeruste skedule-ontwikkeling, aanstelling van toegewyde projekbeplanner- en skeduleerder, sowel as personeelbestuur- en ontwikkeling.

Dedication

Often people only truly appreciate what they have only once they have lost it. This work is dedicated to those people dearest to me, whom without, I would be lost; Darrel, Karen, Lyndi, Nicole, Kirsty, Kirst, my Grandparents, Jean and Tim.

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List of Acronyms and Abbreviations

ANC	African National Congress
B-BBEE	Broad-Based Black Economic Empowerment
BEE	Black Economic Empowerment
BSCOR	Builders' Supply Chain Operation Reference
BIM	Building Information Modelling
BOOT	Build Own Operate Transfer
BOQ	Bill of Quantitates
BOT	Build Operate Transfer
CC	Critical Chain
CCPM	Critical Chain Project Management
CEO	Chief Executive Officer
CIDB	Construction Industry Development Board
CSCM	Construction Supply Chain Management
CSM	Construction Supply Management
DBB	Design Bid Build
DM	Decision Making
EAV	Estimate at Complete
EIA	Environmental Impact Assessment
EMEA	Europe, the Middle East and Africa
EOT	Extension of Time
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement and Construction Management
EV	Earned Value
EVM	Earned Value Management
FEL	Front-End Loading
FIDIC	International Federation of Consulting Engineers
FIFA	Federation Internationale de Football Association
GC	General Contractor
GCC	General Conditions of Contract
HOP	hand Over Point
IRR	Internal Rate of Return
IM	Information Management
IT	Information Technology
JBCC	Joint Building Contracts Committee
JIT	Just-in-Time
JSE	Johannesburg Stock Exchange
JV	Joint Venture
k	Thousands
KPI	Key Performance Indicator
LPS	Last Planner System

LSTK	Lump Sum Turn Key
m	Million
MCDM	Multiple Criteria Decision Making
NPV	Net Present Value
NUMSA	National Union of Metalworkers of South Africa
PICC	Presidential Infrastructure Coordinating Commission
PLC	Public Limited Company
PM	Project Manager
PMI	Project Management Institute
PMBOK	Project Management Body of Knowledge
PWC	Price Waterhouse Coopers
RACI	Responsible, Accountable, Consulted and Informed assignment Matrix
RCA	Root Cause Analysis
REC	Research Ethics Committee
RPD	Rapid Product Development
ROI	Return on Investment
SA	South Africa
SABC	South African Broadcasting Centre
SARB	South African Reserve Bank
SANS	South African National Standards
SC	Supply Chain
SCC	Supply Chain Council
SCOR	Supply Chain Operations Reference
SCRM	Supply Chain Risk Management
SMART	Specific, Measurable, Attainable, Realistic, Time-Based
SME	Small and Medium Size Enterprise
SPI	Schedule Performance Index
SSCM	Sustainable Supply Chain Management
SSM	Sustainable Supply Management
SV	Schedule Variance
TMR	Tasks Made Ready
TOC	Theory of Constraints
TQM	Total Quality Management
t	Tonnes
UK	United Kingdom
USA	United States of America
VKB	Voorsieningskettingbestuur
WBS	Work Breakdown Structure
WIP	Work In Progress
3D	Three Dimensions

Chapter 1. Introduction

1.1 Background to Research Problem

Most, if not all large projects are either delayed or over budget by the time the initiation process is complete and transfer to the operators or owners has taken effect (Ambsisi, 2011). Delays and cost overruns can be attributed to problems with management, supply of resources, design, climatic disruptions, human resources and skills shortages but the reason for delays are often not known. One industry notorious for experiencing regular and costly delays is the construction industry. According to a statement made in his book, *Critical Chain*, *Eliyahu Goldratt* claims that, "everybody knows that projects are delayed and over budget and if they aren't, there was a compromise on content or quality" (Goldratt, 1997).

Considering the so called "world one" problem to be the delay and budget overruns of construction projects, this paradigm defines the problem in a holistic context (Mouton, 2001). The focus of this research will be orientated in the so called "world two" paradigm, with focus on specialised scientific methodology while adopting a critical and analytical analysis approach to the cause and solution to the "world one" paradigm problem. The third paradigm, "world three" is focused on meta-science (Mouton, 2001) and adopts an abstract and philosophical approach to research and theory, this paradigm will not be the focus of this research.

According to authors such as *Venkataraman,* there is overwhelming evidence in support of the drive towards supply chain management, claiming that there are "proven benefits in adopting supply chain management". *O'Brien* goes as far as to claim that construction supply chain management (CSCM) is the new approach to reduce cost and increase reliability and speed of construction processes as early as the late nineteen nineties (O'Brien, 1998). The challenge is then in the implementation of the associated strategies and methodologies that support supply chain management (SCM) and more specifically, for project managers to implement and integrate these strategies into their management of projects, particularly construction projects (Venkataraman, 2004).

This study will thus focus specifically on construction projects in order to assess the effect of conventional project management activities involved in a construction project on the timeliness and cost effectiveness of a specific project. A critical analysis of existing project management procedures and techniques will be conducted. Conventional techniques will be compared and benchmarked against the techniques and processes specified in the Supply Chain Operations Reference (SCOR) model in an effort to assess the adequacy of the SCOR model in managing construction projects. This will be in the form of high level process evaluation of conventional project management, specifically activities associated with construction projects within South Africa

Specific attention will be focused around identifying standard processes, as described in the SCOR model, that describe which activities are performed where and how, namely; plan, source, make, deliver and return (Supply Chain Council, 2014). Identification of the shortcomings and limitations of conventional project management practice will be considered critical to the success of the study along with identification of strategic management processes, SCM management principles as well as potential SCM implementation opportunities where SCM may provide superior management and control of a task. This shall be discussed in further detail in succeeding chapters.

Project management of construction projects is a problem that might need to be tackled from a completely new perspective. Not from a mathematical point of view but rather from a logical point of view, by identifying a logical set of procedures that when implemented will lead to more effective management and control of a construction project. Since the solution might not be in the form of a mathematical model, the solution may be a robust logical procedure that is based on common sense, this will form the premise of this study. Such management principles and theories implemented within the manufacturing industry include but are not limited to, *Just-in-Time* (JIT) and *Total Quality Management* (TQM) as well as *Theory of Constraints* (TOC) being among the many that have revolutionised the way in which managers approach the management of projects. Although current modern day construction management processes and techniques are compatible with the fragmentation that is common in construction projects (O'Brien, 1998), there needs to be an effective, engineering solution developed that enables the management of future construction projects in a collaborative and efficient manner.

A proof of concept study was conducted by means of a traditional case study. Key role players within an organisation involved in construction activities were interviewed by means of semi-structured interviews for the purpose of learning more about their management processes with respect to the design and construction processes of a specific site. One case study is presented in this paper. For the sake of confidentiality, the company and other key role players will remain anonymous, with the main client being referred to as *Company A*.

The academic research team acknowledges that such a case study approach is open to criticism on the basis of lack of measurability due to the fact that gathered data is generally based on perceptions and subjective interpretations of the individual researcher. The consequence being that results may be ambiguous and biased. In an attempt to obtain unbiased data, a triangulated data collection process was used wherever possible. This was achieved by obtaining data through a series of structured interviews and questionnaires as well as a casual interview (discussion) process.

The research team does not regard the findings of the case study conducted on *Company A* as being in any way definitive, but rather as being a starting point for further, more in-depth research.

1.2 Research Question

Will a SCM approach to project management, such as SCOR, improve the cost effectiveness and timeliness of a construction project while maintaining sustainable project management control, compared to conventional project management approaches?

1.3 Problem Statement

Applying SCM principles and techniques to a construction project will improve the timeliness and cost effectiveness of projects and ensure sustainable project management control, as opposed to conventional project management techniques.

1.4 Research Hypotheses

H_o - A SCM approach to project management will improve the cost effectiveness and timeliness as well as allow for sustainable project management of a construction project, as opposed to conventional project management approaches.

H_a - A SCM approach to project management will not improve the cost effectiveness and timeliness or allow for sustainable project management of a construction project, as opposed to conventional project management approaches.

1.5 Research Goals and Aims

An attempt to apply SCM principles to budget and scheduling problems encountered in the construction industry will be the underlying theme of all the research conducted throughout the proposed research process. Comparing existing and accepted project management methodologies with similar SCM and SCOR methodologies, processes and metrics, will orientate the reader with regard to the effectiveness of the current project management solutions and help to draw attention to possible shortfalls in current best practices within the construction industry. Identifying shortfalls in traditional project management techniques and models, such as *the Project Management Book of Knowledge* (PMBOK) and evaluating how these methods measure success based on certain management styles will be a core focus of the proposed research.

At the highest level, our goal is to evaluate the recurring problem of budget and schedule overruns experienced in the construction industry in an effort to improve productivity, efficiency and profitability of construction supply chains whilst still maintaining sustainable project management control strategies.

A key goal will be to measure the performance of existing project management strategies of *Company A* by means of qualitative data. Measuring all performance metrics is an over ambitious goal, however certain key management processes and measurement metrics will be identified and measured. This will quantify management effectiveness and act as a benchmark for improvement. Another aim will be to assess, specifically, the shortfalls of and the opportunities that exist in project management of a construction project based on both a SCM approach as well as conventional PM approach such as PMBOK, in order to evaluate whether successful project management is in fact at all achievable in a construction context.

1.6 Research Objectives

The research objectives outlined below will form the basis of the study.

a. Identify SCM methodologies applicable to project management in the construction industry;
b. Evaluate project management effectiveness based on empirical qualitative data and comparisons with historical project data;
c. Identify factors that cause budget overruns and schedule delays in the construction industry;
d. Identify an effective and sustainable project management strategy, applicable to project-based organisations;
e. Compare, based on empirical measurement, SCM and project management performance measures and metrics related to the construction industry and identify a set of critical project metrics.

The research will evaluate different SCM approaches, in order to identify individual management styles behind each methodology and define where each approach may achieve superior management and control of a certain process in a construction project, based on comparison with conventional PMBOK project management.

1.7 Significance of Proposed Research

Although applications of SCM are extremely diverse and widely applicable, there are few cases where a SCM principle, such as a SCOR-based model, is explicitly used in the construction industry or a construction-related supply chain, such as an attempt by *Thunberg and Persson* to improve construction logistics by means of SCOR model performance measurements (Thunberg & Persson, 2013b).

There thus exists sufficient scope for such research in the fields of construction and project management on the basis that there exists potential financial benefit for organisations that adopt the proposed SCM based approach to sustainable project management.

The construction industry as a whole could potentially benefit from the proposed research if it was to be successful in achieving the stated research goals. Direct benefit, in the form of cost savings would be realised by multinational firms such as *Company A*, the likes of who invest heavily in infrastructure development and construction.

1.8 Limitations and Scope

The intention of this study is to evaluate the feasibility of implementing a SCM approach to project management as a substitute or supplement to PMBOK project management in a South African construction project.

Such a feasibility valuation is complex, especially when dealing with multifaceted projects commonly encountered in the construction industry. Project management as per SCM methodologies, historically applied in manufacturing, will be a core focus of the study. An evaluation as to the suitability of SCM in a temporary-project environment will be conducted on a qualitative basis by means of an extensive literature study, empirical observation and expert evaluation.

The scope of this research will be limited to the construction industry and will focus solely on the management of a construction project, with specific focus on the South African construction industry. Key performance Indicators (KPI's) of projects will be considered to be cost and schedule and the focus of the study will be to improve the performance of these two performance measures, acknowledging however, that there are many more measures of project success beyond cost and schedule. For the purposes of this study, cost and schedule will be considered as the only measures of project success.

The proposed research will centre on the theoretical implementation of SCM principles in a construction project and will involve measuring the performance of a project based on financial and schedule performance. A comparison of results obtained from a case study and those that are expected from the implementation of SCM project management approaches will be conducted to evaluate the similarities and differences between conventional PMBOK project management and SCM.

The external validity of the research may be influenced by an unusual sample of interview candidates, or may only prove applicable in certain specific projects or at a particular point in time. An attempt to improve the validity of this research was made by ensuring that interview candidate selection was based on an accepted sampling model and by ensuring that the sample was representative of the target population. It should be noted that only a single case study was conducted, within a single company, in a single industry from a single sample population using a non-random sampling technique. This approach was deemed satisfactory due to the time constraints and due to the extremely confidential information required for successful completion of this study.

Due to the abovementioned factors, the external validity of this study may be criticised and thus will only be considered applicable to the construction industry in South Africa and replicable only in cases similar to that of the project in the case study.

Similarities and differences between conventional project management and SCM will be based on qualitative data, from both literature and a case study. The study will also focus on a specific supply chain framework, known as SCOR. With regards to SCOR, only an attempt to identify level 1 SCOR metrics will be made. SCOR consists of more than 250 organised metrics. Each metric is either an organisational scope (level 1), process element (level 2) or a level 3 performance attribute diagnostic metric. Each level provides a certain amount of process detail with level-4 being project specific. *Plan, source, make* and *enable* level-1 processes of the SCOR model will be considered in the study, with specific focus on the *source-engineer-to-order product (sS3), make-to-stock (sM1) and make-to-order (sM2)* level-2 processes of the SCOR model. The rationale for this decision being that the above-mentioned processes directly relate to the transfer of activities from on-site to earlier stages of the supply chain when considering a construction project.

Engineer-to-order refers to production methodology where the engineering activities associated with a product contribute significantly to the lead time of that product. For instance, when designing a unique component of a highly specialised, once-off machine, the design lead time of that product is a significant consideration to account for when planning the project or production plan. Often the engineer-to-order processes that are required in a specific project are duplicated in subsequent projects and could eventually, instead of being viewed as an *source engineer-to-order process*, be seen as a *source make-to-order process* since there exists a certain supplier or accountable party that will repeatedly be tasked with the *source engineer-to-order* process, thus essentially rendering this process a *source make-to-order process.*

The ability to identify and isolate occurrences of this nature will be considered an important section of the proposed research. The *source stocked product* processes will be considered applicable only for standard parts and resources - such processes will not be the focus of the proposed study. The development of process descriptions of activities of critical level-3 processes, known as level-4 processes will be briefly considered. Processes in level-4 are specific to industry, location, product and technology and shall all be defined in the construction context by making reference to the Builders Supply Chain Operations Reference (BSCOR) model.

Applications of the SCOR model outside of the construction industry will be considered only as references, direct application of such models or techniques will need to be meticulously evaluated before being considered acceptable. Past attempts to incorporate the SCOR model into a construction environment found the SCOR model too generic for a construction application, with *Thunberg and Persson* describing the model as "too manufacturing orientated for the construction industry" (Thunberg & Persson, 2013b). The above-mentioned possible limitations will need to be considered when assessing the validity of the proposed research in a construction context, noting however, that the construction industry has changed significantly since the attempt by *Thunberg and Persson* to incorporate SCOR in the construction industry.

A further limitation of the study that needs to be acknowledged is the effect of political and economic pressures on the validity of the study. The South African construction industry faces many challenges that are unique, such as political and economic circumstances, wealth redistribution initiatives, corruption, collusion, militant trade unions and uncontrolled and violent strike action. The effect that such factors have on the management of projects is difficult to quantify. It is not the intention of this study to resolve the effects that such factors have on the process of management, although an effort to consider such effects will be made where possible since such factors are a reality in South Africa.

Although it is not the core focus of this study, these factors and their effects on projects will be addressed wherever possible as project management is ultimately directly affected by these factors. Project success, despite implementing the best possible management processes, is not possible without successfully identifying, quantifying and managing such factors.

1.9 Ethical Implications

According to the University of Stellenbosch, "researchers are accountable to society, their professions, the University and affiliated institutions at which they do research, the staff and the students who are involved, and to the sponsor who funds the research" (Stellenbosch University, 2009). In fulfilment of the university requirements, all proposed research will conform to the guidelines as stipulated in the above mentioned official university document. Specifically, conducting any surveys or interviews will require the approval of the Stellenbosch Research Ethics Committee (REC) before the study commences (Stellenbosch, 2013).

1.10 Details of Collaborators

Company A have agreed to fund the proposed research to an amount discussed and agreed upon by the researcher, supervisor and the *Department of Industrial Engineering* - they will provide data that will be used in a case study to verify the applicability of the proposed research, results and recommendations.

Company A is a well-known multinational mining conglomerate with focus on platinum, iron ore and thermal coal. *Company A* was founded in South Africa and continues to have more operations in South Africa than any other country in which they operate. For the purposes of this study, *Company A* is considered to be assuming the role of Client.

Interviewees included two project managers, a site engineer and two foremen employed by *Company A* in managerial capacities as well as five industry experts, including a Junior site engineer, a senior project manager, the director of a prefabrication producer and supplier, a senior consultant from *ipsolutions* and a senior design engineer.

All research will be conducted under the co-supervision of *Mr Konrad von Leipzig,* a senior lecturer in the supply chain field at the *University of Stellenbosch*, South Africa.

1.11 Structure of Thesis

This thesis is organised into nine chapters as outlined in the below sections.

Chapter 1 – Introduction
This chapter presents a basis and purpose for the study and forms an overview of the research, outlining the aims and objectives of the research. The research questions and hypotheses as well as the significance of the research are presented. Also, the limitations, study boundaries and the scope of the research are clearly defined.

Chapter 2 – Literature Review
This chapter forms a comprehensive overview of the existing body of knowledge with regard to the study as a whole. Specific focus was placed on the construction and manufacturing industries, supply chain management as well as conventional project management skills and processes.

Chapter 3 – Research Design and Methodology
This chapter serves as a guide to the research approach, data gathering process, focusing on techniques and procedures. The rationale for the selection of certain techniques is presented. Furthermore, a case study is presented and analysed. The case study is of a construction project, where *Company A* is the client and where various subcontractors have been appointed to complete the construction. The project employed a typical PMBOK management strategy.

Chapter 4 – Results and Findings
A summary of the findings of the case study is presented as well as detailed discussions regarding *Black Economic Empowerment* and project-specific complexities. Instances of SCM and manufacturing principles or methodologies are identified and discussed.

Chapter 5 – SCM Implementation Considerations
This chapter discusses the challenges of implementing SCM in a project environment and highlights the opportunities for SCM to improve PMBOK project management processes. The shortcomings of projects managed by PMBOK principles are identified and discussed. SCM as a supplement to PMBOK is discussed and key project metrics are selected based on recommendations from literature and empirical observation but mainly by evaluating input and recommendations from industry experts.

Chapter 6 – Discussion
This chapter serves to discuss what the findings mean in relation to the theoretical body of knowledge on the topic. This chapter is directly related to the information gathered and analysed in *Chapter 4*. An attempt to answer the “so what?” question is made in this chapter based on both the theoretical

body of knowledge and the case study presented in *Chapters 3* and *4*. In some cases, new literature was introduced to supplement the qualitative data presented in *Chapters 3* and *4*. The practical implications of the research is discussed, making use of the limited quantitative data obtained from *Company A*. Lastly, this chapter assesses the company of the future and evaluates the changing business world as well as discussing the ever-changing drivers, values and expectations of human resources.

Chapter 7 – Conclusion

This chapter serves to combine conclusions of each chapter into a global conclusion. The problem statement and hypotheses are reviewed, discussed and where necessary, modified. This chapter serves to tie up the thesis and presents recommendations for future research.

Chapter 8 – List of References

Chapter 9 – Appendices

Chapter 2. Literature Review

To accurately delineate the area of the research that is to be conducted and to better position the reader in this research field, section 2.1 will briefly describe the overall concept of supply chain management (SCM) as well as discuss key concepts of SCM. Section 2.2 will discuss in more detail the supply chain council as well as the supply chain operation reference model, its applications and benefits as well as briefly discussing the emergence of a specialised builders supply chain operations reference model. The South African construction industry as well as its relation to the South African economy is discussed in section 2.3. Section 2.5 further investigates and discusses the prevalence of SCM in the construction industry in an attempt to categorise the similarities that exist between manufacturing and construction as well as investigating the economics and feasibility of manufacturing type principles in the South African construction industry. Sections 2.4.6 and 2.4.7 specifically focus on project time management and the theory of constraints (critical chain) respectively.

2.1 Supply Chain Management

Supply chain management (SCM) “will ultimately separate the winners from the losers” (Spekman, Spear & Kamauff, 2002). In the modern-day management arena there is no doubt that SCM is a hyper-topic (Otto & Kotzab, 2003) that has progressively become the foci of enterprise and academia since as early as the 1980’s (Shu, Chen, Wang & Lai, 2014). The potential of SCM lies in the systems view of production activities that allows better understanding of manufacturing costs and production capabilities (O’Brien, 1998).

SCM involves the streamlining of supply activities of a business in an effort to gain a competitive advantage and maximise customer value in a particular field. SCM involves the interaction of different value adding supply companies of a “supply base” that develop and coordinate their supply chains so that they are as economical and efficient as possible in achieving a specific objective (Makris, Zoupas & Chryssolouris, 2011). A company’s supply chain is generally comprised of many facilities and assets that interact on a global level in order to achieve a unified objective; each facility contributing to either, or a combination of, raw materials, intermediate or finished products and value-adding service to the overall supply chain objective. Through collaboration between different companies in a specific SC, the overall supply chain can operate in a more efficient and profitable way in order to produce a product or provide a service (Ellinger, Shin, Northington, Adams, Hofman & O’Marah, 2012). Critical areas that SCM is focused on include customers, suppliers, design and operation, logistics and inventory (Venkataraman, 2004).

Interest in SCM in recent years has snowballed and through the work of academics and practitioners and thus the benefit of effective implementation of SCM has been identified and quantified through both quantitative and qualitative research. *Ellinger* suggests that SCM has an impact on each of the key drivers of a firm’s performance which subsequently leads to various benefits, such as improvement of the overall performance of a supply chain (Ellinger et al., 2012). Lower costs, higher return of investment (ROI) and a higher return to shareholders are among the benefits that can be expected from a shift of attention towards the supply base (Spekman et al., 2002). The processes that are collectively known as SCM if implemented correctly, can have a significant and indeed, a positive impact on a company's supply chain. SCM involves organisations, procedures, activities as well as people, in an effort to focus on key business areas such as enterprise development, order management, warehouse distribution and demand planning. The benefits that arise from this explicit and focused effort is that there can be either a reduction in uncertainty along the entire supply chain, more efficient inventory management, fewer delays, improved customer service and fewer accelerated critical activities. Effective SCM will result in significant improvement in customer satisfaction, cost, flexibility, delivery speed and reliability as well as handling customer complaints (Bernardes, Ednilson, Zsidisin & George, 2008; Fan, Zhang, Wang, Yang & Hapeshi, 2013).

Supply chains, especially when dealing with global organisations that are commonplace in the twenty-first century, can be extremely long and complex, with issues ranging from cross-border problems, customs taxes and politics to the need for critical information technology support. There also exists a common trend between managers and employees whereby they are hesitant to adopt a new system or approach to what they have grown accustomed to in the past, which can prove to be a hindrance to SCM. This mental block is something that will require a concerted effort on the part of the employer and the entire project implementation team. In order to overcome scepticism, there needs to be clearly defined goals that are easily quantified and measured by management in order to monitor and gauge progress. Fragmented supply chains, unavailable data, unwillingness to cooperate and a culture of one-of-a-kind projects are possibly the greatest challenges facing the implementation of SCM in the modern day construction site. These problems have been considered when the supply chain council made an attempt to develop a globally accepted model of reference, the SCOR model. However, SCM continues to influence, and often dictate management decisions and is considered to be an invaluable tool in successful modern day management (Spekman et al., 2002). Typical SCM approaches consider single supply chain material and information flow to improve the decision making process, material and information flow can occur between companies as well as internally within individual companies. Decision making (DM) processes occur at strategic, tactical, and operational DM levels (Zamarripa, Hjaila, Silvente & Espuña, 2014).

A relatively new trend is that of a holistic approach to SCM. Holistic supply chain management is a process of analysing a supply chain from a holistic point of view, considering the overall impact of decisions, not just simply the localised impacts of decisions. Authors such as *Womer* discuss the consequences of overlooking the importance of the holistic view of the supply chain (Li & Womer, 2012) and *Ellinger and Shin* discuss the growing consensus among researchers that a holistic approach to SCM requires the use of different methodological approaches (Ellinger et al., 2012).

SCM is thus still a relatively new, developing and evolving field of study, with different authors specifying different best-practices associated with managing a supply chain. However there exists no single generic "best method" or "best approach" to SCM since the complex nature of supply chains limits the applicability of certain approaches. According to *Kocaoğlu*, due to the fact that there are so many different views "on what should constitute supply chain performance" many organisations have found it difficult to practice SCM effectively (Kocaoğlu, Gülsün & Tanyaş, 2011). It is thus the opinion of industry that each individual supply chain should be evaluated based on its specific, unique characteristics and requirements in order to develop and refine a SCM technique or approach, this can be achieved by implementation of the supply chain operations reference model (Zangoueinezhad, Azar & Kazazi, 2011).

During the late 1990's and early 2000's the drive towards SCM in the retail and manufacturing industries had been extensively documented along with the associated benefits of effective SCM, such as reduction in inventory, improved customer service, shorter cycle times and lower logistics-related costs (Venkataraman, 2004). Applications of SCM within the manufacturing sector have led to savings in billions of dollars as well as improving customer service levels according to *O'Brien* (O'Brien, 1998). Although prevalent in retail and manufacturing, project based organisations failed to implement SCM concepts and strategies in early years and as a result are still developing SCM techniques to improve their supply chain processes in an effort to gain significant competitive advantage in the market. According to *Venkataraman* there exists evidence that "40 percent of the amount of work constitutes non-value-adding activities such as time spent on waiting for approval or for materials to arrive on project site" when referring to the construction industry (Venkataraman, 2004).

2.1.1 Supply Chain Management Sustainability

Sustainability is achieved through realising a balance between the three main components of sustainable development - social development, economic development and environmental protection (Brandenburg, Govindan, Sarkis & Seuring, 2014).

Sustainability, much like SCM, has been the focus of extensive research and attention in the media in past years. Despite this, sustainability remains poorly defined and there is little known about barriers and drivers associated with adopting environmentally sustainable practices within an organisation. According to *Giunipero*, "this is particularly true with regard to implementation in the purchasing and supply management function" (Giunipero, Hooker & Denslow, 2012). Intersection between supply chain management and sustainable development has developed extensively in recent years (Gold, Hahn & Seuring, 2013), driven by stakeholder pressure to sustain the performance of an entire supply chain. Originating from a drive to maintain a triple bottom line, defined by *Investopedia* as "an effort to advance the goal of sustainability in business practice" (Investopedia, 2014), industry integrated sustainability into its existing SCM and supply management models. It thus comes as no surprise that the concept of sustainability and supply chain management were merged to form the concept of Sustainable Supply Chain Management (SSCM) and on a more detailed level, Sustainable Supply Management (SSM).

There are, however, problems with the above-mentioned models, in particular the SSCM model.
The problem with the SSCM model is that the underlying focus of this model is based on sustainability and thus the entire model has been developed in order to promote sustainability within the supply

chain which at the end of the day leads to improvement in a supply chain's sustainability (Gold et al., 2013). This results in a specific supply chain design that is geared for sustainability. This logic is illustrated in Figure 2-1.

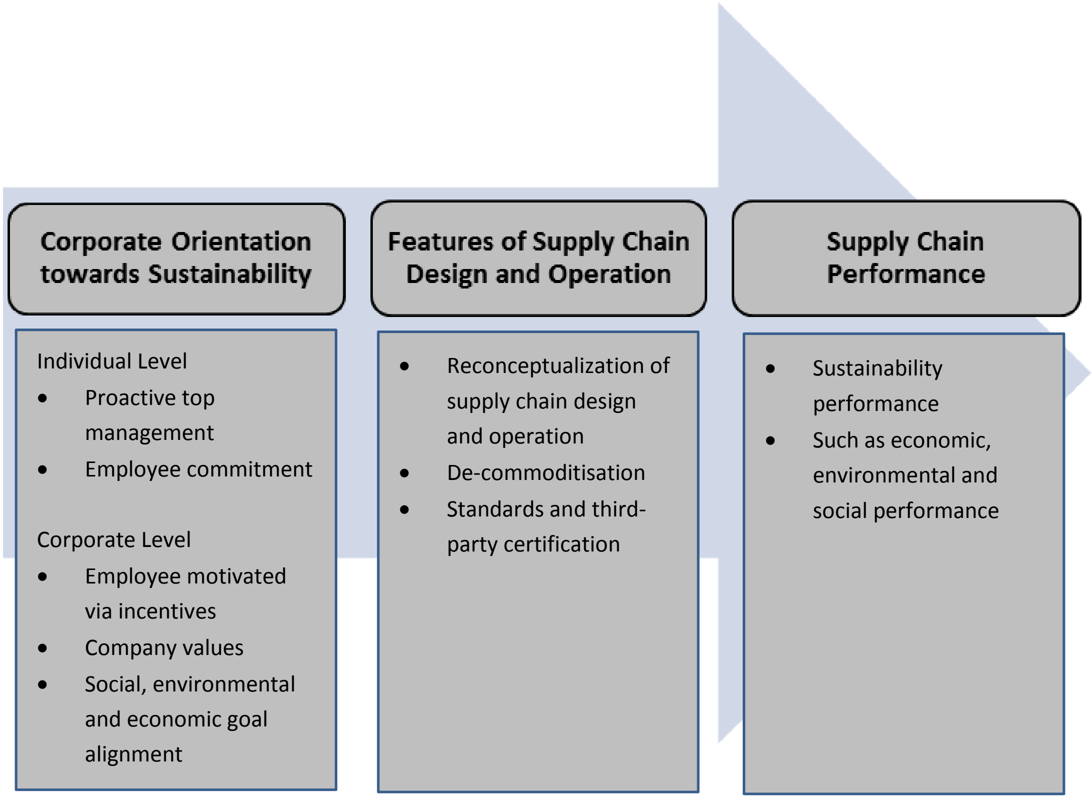


Figure 2-1: Sustainable supply chain management (Gold et al. 2013)

On the corporate level, the orientation of an organisation towards sustainability is what will guide a corporation to achieving holistic sustainability. This is the so-called driver of sustainability within a corporation. Without the backing of high-ranking management officials, sustainability in a supply chain is simply not attainable. On the individual level, sustainability is achieved through the collaboration of individuals, each acting in a sustainable manner via top management's endorsement of sustainable practices. Motivation is often provided in the form of incentives or formal recognition (Gavronski, Klassen, Vachon & Nascimento, 2011).

The world is moving towards sustainability and a sustainable future, forcing industry to follow, including the construction industry. The sooner organisations adopt a sustainable approach to their supply chain and supply management, the greater the benefit for the organisation and the greater the opportunity to gain significant competitive advantage in the marketplace. This concept is in line with the narrative of the company of the future, of which construction companies will be a part of and thus need to adapt to fulfil this narrative. In the future, all companies and their practices will need to be as sustainable as possible in order to preserve both limited natural resources as well as the environment, yet another potential benefit of SCM. It is deemed to be a sustainable practice and sustainable business practices are expected to drive the economy of the future (Berkinshaw, 2013).

SCM is thus not a completely foreign approach to manage a construction project. Based on solid and sustainable engineering principles, able to design, plan and manage all aspects of a construction project in a collaborative fashion, SCM may just be the solution to the rather serious problem currently faced by the global construction community.

2.2 Supply Chain Council

The Supply Chain Council (SCC) is "a global non-profit organization whose framework, improvement methodology, training, certification and benchmarking tools help member organizations make dramatic, rapid and sustainable improvements in supply chain performance" (Supply Chain Council, 2014).

Through market-driven necessity, two consulting firms - *PRTM* and *Advanced Manufacturing Research* (*AMR*) set out to develop a reference model in order to support the drive towards process-based management (Stewart, 1997). In 1996, together with a group of experienced operations, manufacturing and supply-chain managers from various industry-leading companies as well as USA and multinational firms, a group was formed, the SCC. The SCC later helped to develop, test, refine and release the reference model known as the SCOR model (Stewart, 1997). This model was a result of the collective work and research of more than seventy international manufacturers in the late nineteen nineties (Zangoueinezhad et al., 2011). The purpose of the SCC is to provide their member companies with the knowledge and resources to develop, manage and lead a high performance supply chain. Supply chain professionals within member organisations gain superiority over their competitors through implementation of frameworks, benchmarks, networking, professional development and certification, to name a few.

The SCC operates on a global basis with local chapters in existence in key regions, South Africa being a key region. Members are afforded the opportunity to participate on a global or local basis, depending on their individual supply chain requirements. Member organisations have full access to the tools, research and networking opportunities provided by the SCC in order to accelerate and increase supply chain management processes and results (Supply Chain Council, 2014). Worldwide the SCC is supported by over 1000 member organizations both in academia as well as industry (Supply Chain Council, 2014) all of whom benefit from or implement the SCOR model, the flagship framework of the SCC.

2.2.1 Supply Chain Operation Reference Model

SCOR, developed and maintained by the SCC is regarded as the world standard for SCM (Supply Chain Council, 2008), used for describing and improving operational process effectiveness. The SCC further developed the SCOR framework to version 11, released in 2013. The SCOR model is a process reference model that provides the framework and a standard language of communication among SC partners such as suppliers and customers (Bartakkeomkar, 2011). SCOR is a unique, cross-industry standard reference model (Stewart, 1997) that provides a framework for describing, measuring, evaluating and linking performance metrics, processes, best practices, and people and skills into an integrated structure that can be analysed to dictate managerial decisions (Zhou, Benton, Schilling & Milligan, 2011). It is a management tool that can address, improve and coordinate SCM decisions within a company, its customers and its suppliers.

Figure 2-2: The six management processes of SCOR (Supply Chain Council, 2008)

The model can map, benchmark and improve a supply chain (Persson, 2011) by bringing order and logic to the activities that make up a supply chain and providing standard terminology and process descriptions. Activities in the SC are regarded as a series of interlocking, inter-organisational processes, each based on five primary management areas: Plan, Source, Make, Deliver and Return as shown in Figure 2-2 (Zangoueinezhad et al., 2011).

This enables companies to efficiently evaluate and benchmark processes both inside and outside their industry segment. The SCOR model incorporates all customer and market interactions, as well as physical transactions and thus provides a comprehensive overview of all business processes. All business processes are grouped and assigned to one of the five primary management areas. The model is intended to be used as an analysis tool for analysing a supply chain at multiple levels, namely levels 1, 2, 3 and 4, as shown in Figure 2-3.

	Level		Examples	Comments
	#	Description		
Within scope of SCOR	1	Process Types (Scope)	Plan, Source, Make, Deliver, Return and Enable	Level-1 defines scope and content of a supply chain. At level-1 the basis-of-competition performance targets for a supply chain are set.
	2	Process Categories (Configuration)	Make-to-Stock, Make-to-Order, Engineer-to-Order Defective Products, MRO Products, Excess Products	Level-2 defines the operations strategy. At level-2 the process capabilities for a supply chain are set. (Make-to-Stock, Make-to-Order)
	3	Process Elements (Steps)	• Schedule Deliveries • Receive Product • Verify Product • Transfer Product • Authorize Payment	Level-3 defines the configuration of individual processes. At level-3 the ability to execute is set. At level-3 the focus is on the right: • Processes • Inputs and Outputs • Process performance • Practices • Technology capabilities • Skills of staff
Not in scope	4	Activities (Implementation)	Industry-, company-, location- and/or technology specific steps	Level-4 describes the activities performed within the supply chain. Companies implement industry-, company-, and/or location-specific processes and practices to achieve required performance

Figure 2-3: Different hierarchical processes within the SCOR model (Supply Chain Council, 2008)

The main focus of SCOR is on the top three process levels, those which are considered to be industry neutral (Bolstroff, 2007), although any company that intends to implement supply chain improvements based on the SCOR model will have to individually analyse their model to level 4 in order to adjust and account for specific operational requirements of different companies. The model focuses on describing processes, while avoiding any specific functions or organisational components. Strategic processes are measured by means of KPI's. KPI's are considered to be a common tool for assessing the extent to which an organisation is achieving its strategic goals (Thunberg & Persson, 2013b). KPIs are level-1 metrics and there are a total of eleven KPIs in the SCOR model, often grouped according to performance attributes.

By implementing the SCOR process framework, the development of enterprise level measurement and architecture can be accelerated, translating into better communication and results in rapid development by managers (Supply Chain Council, 2008). SCOR focuses on the supply chain that comprises of raw materials through to the consumer with a holistic approach, from "rock to ring". This implies that the supply chain is responsible for the entire lifecycle of a product, from when it's mined as a "rock", to when it is produced into a "ring" and then eventually recycled.

The SCOR model consists of two distinct parts, the SCOR project and SCOR framework. The SCOR project is concerned with facilitating change through a "change project" that involves steps for identifying a supply chain, strategic requirements and a road map for improvement. These steps are called phases and are listed in Table 2-1.

Table 2-1: Phases of SCOR implementation (Thunberg 2013)

Phase	Focus	Description
0	Organise	Identify a project team and available resources required for the successful implementation of the change project.
1	Discover	Explore potential opportunities through SC identification and prioritisation. Rank SC based on importance of the SC to the company, this identifies the SC's that need to be focused on in the change project.
2	Material	Mapping the flow of materials in order to identify problems geographically and on a logic level using predefined SCOR process definitions in a hierarchical manner into three levels. This identifies the SCOR processes that must be improved in order to improve SC performance and provides a comparison with competitors SC's.
3	Analyse	Identify relevant metrics that will be measured in order to determine which attribute (based on data); reliability, responsiveness, agility, cost or assets, will for each SC be considered to be either parity, advantage or superior. This allows explicit focus on specific key metrics in each SC.
4	Work	Identification of improvements, solutions to the identified problems in each SC. The SCOR manual has a list associated with each improvement suggestion for each SCOR process based on best practices.
5	Implement	Implementation of the suggested solutions is executed in each SC. This is a company specific phase – no generalisation can be made in this regard.

The phases in Table 2-1 outline the fundamental purpose of a reference model, to facilitate the integration of common business concepts such as benchmarking, re-engineering and process measurements into a multidisciplinary and cross-functional framework. The key to the success of a management model lies in the contents of the model. The model requires all of the following attributes: definitions of standard practices, relationships between standard practices, standard metric definitions, proposed management practices that produce best-in-class performance as well as standard alignment to features and functionality. The overarching benefit of implementing a process reference model is the fact that complex management processes and plans can be dissected into more manageable standard processes. This ensures that the tasks at hand are correctly and strategically implemented, easily measured, clearly communicated and fine-tuned to suit specific situations (Bartakkeomkar, 2011). The fact that a well implemented process reference model has the potential that has just been discussed is clear evidence that this model is potentially an extremely powerful tool for management to utilise with virtually unlimited possibilities for application (Thunberg & Persson, 2013b).

2.2.2 Applications of SCOR

Applications of the SCOR model are diverse and cross-industry applicable and SCOR has consequently been adopted by many companies and conglomerates world-wide (Stewart, 1997). According to authors such as *Bauhof* , if an organisation has no control over its supply chain or if that company lacks the support of management when it comes to the improvement of the supply chain, then the SCOR model is the starting point for that company (Bauhof, 2004). Reported evidence in the form of trade journals suggests that companies that have adopted the SCOR model have experienced significant improvements in their supply chain activities (Zhou et al., 2011). There has been extensive implementation of SCOR in the modelling environment and according to *Persson*, the use of the standardised SCOR model allows for faster model building and the predefined definitions and easy-to-understand processes and metrics defined in SCOR are suitable to the modelling processes (Persson, 2011). Other applications, as described by *Zhou,* incorporate the SCOR model into a supply chain of a company. This is possible as the SCOR model focuses on the SCM function of a company from a process perspective, whilst still incorporating customer and market interactions as well as physical transactions. An effort has also been made by researchers such as *McCormack* to link supply chain performance to SCOR planning practices, where it was concluded that "planning processes are important in all SCOR supply chain planning decision areas" (Iii & McCormack, 2004).

With the modern corporate world dominated to a large degree by information technology (IT) systems, numerous efforts have been made to incorporate SCOR processes into the IT framework that drives modern day business; one in particular is the use of the SCOR model to configure computer-assisted supply chains (Huang, Sheoran & Keskar, 2005). Another IT based application of SCOR is in the simulation environment where the development of a dynamic supply chain analysis tool was attempted by *Persson*, integrating SCOR and discrete event simulation (DES) (Persson & Araldi, 2009).

More industry specific applications of SCOR exist, such as in the ship building industry, where the SCOR model has been extensively applied in parallel with so-called fuzzy multiple criteria decision making (MCDM). The study involved using fuzzy screening for selecting indexes for evaluating SC competitiveness (Zangoueinezhad et al., 2011). Another specialized application of the SCOR model was an attempt by *Wang and Chan* to align business process re-engineering by implementation of global supply chain systems, useful in supply chain planning activities (Wang, Chan & Pauleen, 2010). Performance metrics of the SCOR model are beneficial, not only for planning but also for measuring performance, as is described by *Radivojević* in an attempt to model supply chain risk (Radivojević & Gajović, 2014) and also discussed quite extensively by *Wang and Dismukes* in discussing "product driven supply chain selection" (Wang, Huang & Dismukes, 2004).

From the rather extensive list of applications of the SCOR model and its associated methodologies it is clear that the SCOR model is an extremely flexible tool, applicable for use in many diverse fields of study, for a number of different applications ranging from analysis to planning to performance to modelling.

2.2.3 Benefits of the SCOR Model

Problems encountered in construction, originating from poor management, poor coordination or poor planning, all need to be identified, mitigated or eliminated, but the question is how this can be done. Authors suggest that the solution lies in the adoption of a structured framework, of which SCOR is an industry leader (Thunberg, 2013). The implementation of a structured framework such as SCOR is expected to enhance coordination and transparency, improve supplier and subcontractor integration and communication concerned with planning, in addition to enhancing supply chain performance (Rudberg, Persson & Thunberg, 2013).

The SCOR model is a cross-functional process reference model that principally combines business processes such as best practice, benchmarking (through SCOR-mark) and process re-engineering whilst making use of effective process measurement in order to provide reliable cost benefits. The model provides SC definition, process mapping, performance metrics and benchmarking from a pool of more than 800 reference companies, all leading to performance improvement through taking advantage of change, a significant advantage for any company (Agile TV Productions, 2013). The process of implementing the SCOR model results in the analysis of many levels of process detail to assist a company investigate its supply chain structure and performance. The SCOR model provides an insight as to how advanced a company's supply chain is at a specific moment in time. The model assists companies in understanding how the 5 steps reiterate over and over between suppliers, the company, and customers (Bauhof, 2004). The model thus provides a platform from which companies can leverage their entire supply chain by providing them with this specialised, company-specific platform that promotes collaboration and transparency, to name a few. The SCOR model also plays an extremely important role in identifying problems in the supply chain such as poor information flows, ineffective suppliers and bottleneck activities.

SCOR also allows for the rapid development of process architectures without much effort or investigation. Authors such as *Bauhof* claim that " the SCOR model has proven to benefit companies that use it to identify supply chain problems as well as reinforcing and supporting full leverage of capital investment, creation of a supply chain road map, alignment of business functions, and an average of between two and six times return on investment (ROI)" (Bauhof, 2004). Another benefit of the SCOR model is its ability to measure and quantify the value of strategy. The model proves to be an effective measurement tool for translating strategy into supply chain performance objectives by means of prioritisation and linking of performance metrics to financial indicators such as profit and loss (Wang et al., 2004; Huan, Sheoran & Wang, 2004). In summation, the SCOR model increases operating results by an average of 3% in the initial SCOR implementation phase by implementation of cost reduction and customer service improvement. This leads to an increase in profitability of between 2 and 6 times when considering project investment costs in the first year of implementation. The minimization of the requirements of IT customization leads to significant IT cost reduction. Thus the SCOR model has the potential to reduce overall operating cost, improve investment portfolio selection and to optimize company resource planning (Poluha, 2007).

As discussed in this section, there exists significant opportunity for the building and construction industry to warrant the adoption of the SCOR model. There is overwhelming evidence in support of a SCOR approach to SCM in the construction industry, so much so that there has been a model developed specifically for the building/construction industry, known as BSCOR, the Builders' SCOR model (Thunberg & Persson, 2013b; Persson, 2011; Bolstroff, 2007; Poluha, 2007; Thunberg & Persson, 2012; Pan, Lin & Pan, 2010; Thunberg, 2013; Rudberg et al., 2013).

2.2.4 The Builders' SCOR Model

The Builders' Supply Chain Operations Reference model (BSCOR) is an adaptation of the SCOR model that is specifically focused on the building and construction industry. Since the SCOR model was initially developed through cooperation with manufacturing companies for the manufacturing industry, applications of the SCOR model in industries other than manufacturing requires certain adaptations to account for the complexities of each distinctive industry application. This is true for both the medical healthcare field and the after-sales realm of retail, both of these specialised SCOR models being developed specifically to deal with the intricacies of each industry. The same is now true for the construction and building industry with the development of the BSCOR model, a purely construction focused SCOR model (Rudberg et al., 2013). *Micael Thunberg* along with his supervisors, *Fredrik Persson*, and *Martin Rudberg* set out to develop the BSCOR model out of a perceived lack of supply chain frameworks for the mapping and measuring of logistic activities and performance in construction supply chains worldwide (Thunberg, 2013).

One of the prerequisites for effective SCM is the correct coordination and planning of resources and materials between the myriad of role players that are concerned with a construction project. This is exacerbated by the fact that typical construction supply chains are, owing to their project-based nature, temporary as well as being frequently fragmented when considering supply and coordination both on and off site (Rudberg et al., 2013). Planning and coordination of on-site activities are the responsibility of the principle contractor where they are responsible for the coordination and planning of their suppliers and subcontractors and all associated suppliers and logistical concerns. This in effect means that the principle contractor is required to manage across multiple supply chains at the various stages of the project such as planning and production phases, each SC is unique in various ways, each with its own set of unique management and coordination challenges (O'Brien, 1998).

Through analysis of literature investigating construction planning, various problems were identified that arise in planning phases of projects and are as summarised in Table 2-2. These encapsulate generic problems, with planning specifically, that have plagued and continue to plague construction projects.

Table 2-2: Typical planning phase problems and the effects thereof on the project (Thunberg, 2013)

Area	Problem	Pre-Construction	On-site implications
Relationship	Different meanings	Increased amount of rework as plans has to be changed	
	Exclusion	Suppliers unaware of the project's needs and problems with material deliveries	Suppliers unaware of the project's needs.
	Unfamiliarity	Excessive reworks and changes	Problems with material deliveries
Information	Information shortage Information	Misallocation of materials, poor preparation, no information or improvement of plans	Variety in planning and where to place materials etc.
	Inadequate cognition		Increased flaws and reworks as plans are poorly developed
	Interdependency		Time wasted while waiting for others
Complexity	Project uncertainty		Poor and faulty plans and Schedule variance
	Local variations		Schedule overruns
	Dynamic projects		Poor decision-making and non-realistic out-puts as well as a lack of resources when needed
	Intricacy neglected	Impacts time, value, quality, the number of task conflicts and safety	
Resources	Hastiness	Increased level of risk and inaccurate financial estimation	
	Rate and Repetitiveness		Time wasted whilst waiting
	Workflow planning		Wrong tasks and activities performed at the incorrect time, leading to conflicts
	Flows and Inventories	Too much material and stock on-site	Cluttered site conditions and poor material management

Table 2-3 lists identified problem areas commonly encountered in the construction industry, provides a short description of these areas and provides a proposed outline of how the specialised BSCOR model can address each of the identified problem areas. This highlights the benefit of implementing a standardised framework such as BSCOR.

Table 2-3: Problem areas and potential improvement through BSCOR (Thunberg, 2013)

Problem Area	Description of problem	Potential for improvement through BSCOR implementation
Lack of coordination	Poor coordination of work among members leads to widespread reworks and ultimately a delayed project	Develop and implement a procedure for how to plan and distribute plans among members
Not considering contextual differences	'Solutions' developed for other manufacturing industries cannot be directly transferred to the construction industry	Including construction 'Best Practices', metrics, and definitions solely developed for the construction industry
Not improving customer service	A perceived lack of not focusing on improving overall customer services	Standardised system for mapping and measuring that contains relevant metrics
Not inhabiting a trustful climate	A hostile environment among project members often stem from not understanding each other, not knowing what the others are doing, and unstable relationships	Predefined metrics and process definitions results in talking the same language. Identify problematic relationships and resolve them.
Construction supply chains are loosely coupled	Not learning from other projects, not learning from other companies, myopic climate, etc.	Identify Best Practices and report on them. Scrutinise the supply chain and identify problems to overcome
Not adhering to time schedules and budget	How do we measure adherence to time schedule and budget? Adherence to time schedules and budgets are not measured, compared, and followed up systematically today	Standardised metrics and measurement to use for keeping track on time and cost adherence. Evaluate trends in time and cost adherence.
Not learning from other projects	Supply chains are loosely coupled and thus work in isolation	A standardisation model will allow collaboration within SC operations
Fragmented industry	Lack of collaboration	Via a standardised procedure for planning and sharing information independent on who joins the project
Autonomous projects	Construction supply chains are generally loosely coupled	Implement a framework to facilitate collaboration
Planning	There exists a lack of coordination among stakeholders	Provide a framework to facilitate coordination among stakeholders
Not talking the same language	Stakeholders all communicate and measure different things in different ways	Develop an industry standard
Not sharing information	Wrong drawings and information might lead to reworks	Via standardised procedures for sharing plans and information
Not measuring supplier performance	Problems encountered already at the supplier site can develop to bigger problems further down the chain.	Standardised metrics and measurement for assessing supplier performance
Problems propagate	Poor measurement of supplier performance	Implement supply chain performance measurement

As a result of the planning phase problems that have been identified and elaborated upon in Table 2-2 and the problem areas and potential for improvement that were highlighted in Table 2-3, there have been some significant alterations made to the generic SCOR model as outlined below, including new level one and two metrics and measurements.

These amendments to the SCOR model form the BSCOR model which is a model that is applicable to the construction industry. The changes are outlined in Table 2-4. A complete summary of the changes to the SCOR model are provided in *Appendix A*, Table 2-4 serves only as a reference to the abovementioned changes.

Table 2-4: A summary of the changes made to the SCOR model to create the BSCOR model (Thunberg, 2013)

		Revision 1 - 2012	Revision 2 - 2013	Revision 3 - 2013
Processes	Level 1	-	Make process renamed to Build (denoted bB)	-
	Level 2	Change the Source level 2 processes to Source Construction Materials (bS6), Source Resources (bS7), and Source Subcontractors' Materials (bS8)	Added two processes, Build Contractors (bB6) and Build Subcontractor (bB8) -	Added the processes Plan Build (bP7) and Plan Handover (bP8)
	Level 3	• Added a second verification activity in the sourcing processes (bS6.8) • Revised the first verification process (bS6.5) • Removed the installation activity (sD1.14, sD2.14, sD3.14)	• All level 3 processes for Build are new and are derived from (BI, 1999) • Addition of a notify activity in the Deliver process (bD1.13, bD2.13 bD3.13)	Addition of the Balance Sourcing Plans activity (bS6.5) and Establish Master Sourcing Plans (bS6.6)
Metrics	Level 1	-	Addition of a number of movements metric (bRL.1.4)	-
	Level 2	Addition of a notify in time metric in the Perfect Order Fulfilment (denoted bRL.2.5)	-	-
	Level 3	-	-	-
Other		Deliver to the customer process renamed to Handover (denoted bH)	Incorporate the Produce and Test activities in the level 3 process definitions	Identify that contractor and subcontractors should do their plans on their own first and balance them later on

Although the potential benefit of implementing a BSCOR model in the building and construction industry has been made clear, along with a comprehensive summary of the changes made to SCOR in order to develop BSCOR, there has yet been an effort made to indicate the physical, tangible outcomes of the BSCOR model.

Table 2-1 in section 0 highlighted and described the five phases of a SCOR implementation.
Table 2-5 describes the deliverables associated with each SCOR phase and serves to link each phase to an outcome, or KPI, that is directly applicable to the construction industry. This will highlight the potential benefit of implementing a standardised model such as BSCOR for the construction industry that a manager or non-supply chain practitioner can quantify and visualise. When evaluated in conjunction with Table 2-3, Table 2-5 summaries the measurable business and operational outcomes that can be expected when implementing the BSCOR model, however, the BSCOR model should be seen as a continuously developing framework and documentation (Thunberg, 2013; Rudberg et al., 2013; Thunberg & Persson, 2013a).

Table 2-5: Deliverables and potential outcomes of the BSCOR model (Thunberg, 2013)

Phase	Stage	Deliverables	Outcome
0	Organise	• Organisational support structure	Definition of the project team.
1	Discover	• Supply chain definition • Supply chain priorities • Project charter	Outlines the project scope.
2	Material	• Geographic map • Thread diagram • Disconnect analysis	Evaluation of material logistic efficiency and adequacy.
3	Analyse	• SCOR-card • Benchmark • Competitive requirements	Provides an insight as to the performance of the company and its supply chains. Definition of strategic requirements and focus areas.
4	Work	• Transaction analysis • Level 3 and level 4 processes • Best practices analysis	Analysis to ascertain whether company processes are efficient and effective.
5	Implement	• Opportunity analysis • Project definition • Deployment organisation	Definition of potential financial opportunity and a roadmap deployment strategy.

This is the work that constitutes the change from SCOR to BSCOR and as discussed earlier, is still a work in progress. The model still requires further industry validation through real-life implementation as well as individual consultation with managers and personnel involved with the management and operation of a construction project.

However, an industry-specific standardisation model such as this is a step in the right direction for the construction industry and according to *Thunberg* and *Persson*, promises a bright supply chain future for the industry as a whole (Thunberg & Persson, 2012).

2.3 The Construction Industry

2.3.1 The South African Construction Industry

The South African construction industry has been ear-marked for growth and development from as early as 1993, it was expected that the industry would play a pivotal role in the socio-economic development of the country (Ofori, Hindle & Hugo, 1996). Along with steady growth in the construction industry between 1999 and 2008 and with the successful bid to host the *2010 FIFA Soccer World Cup* this expectation was fulfilled. As indicated by the *South African Reserve Bank* in Figure 2-4, the Gross value added at basic prices of construction is increasing year-on-year (SARB, 2014), a positive sign for the construction industry in South Africa.

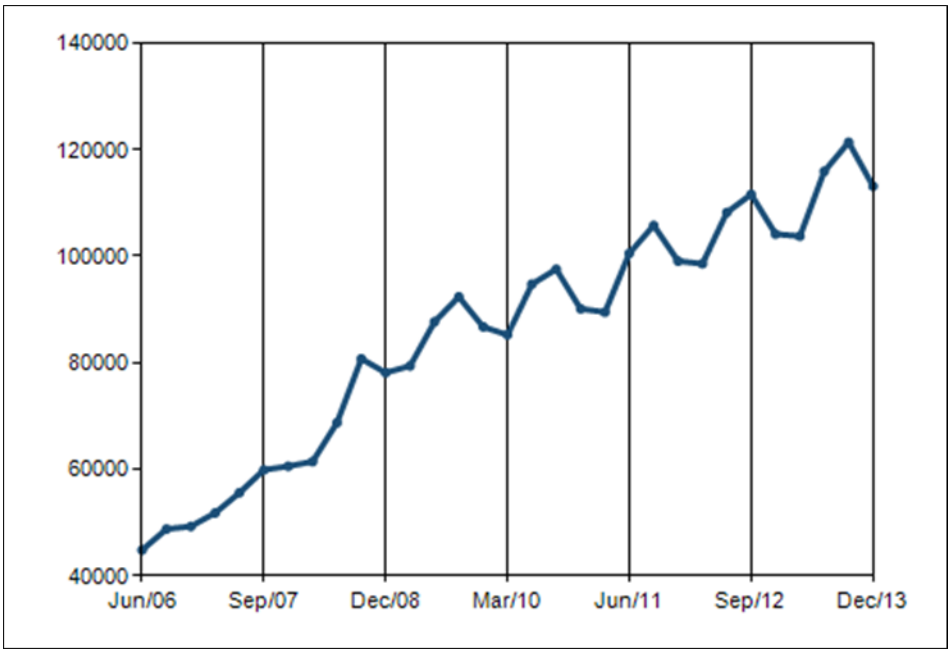


Figure 2-4: Gross value add at basic prices of construction (SARB, 2014)

With R9 billion spent on stadium upgrades and an additional estimated R10 billion spent on road, rail and air-link upgrades as well as a R3 billion upgrade of ports of entry, it is clear that the construction industry, even a single project, can involve expenditure in the tens of billions of rands. According to official published government reports, in excess of R24 billion was spent on infrastructure-related upgrades for the 2010 FIFA World Cup, essentially a " single, isolated project" (Saturday Star, 2012). This provides clear proof that there exists vast opportunity in the construction industry in South Africa and forecasted GDP growth of 3.5 percent in 2014 and 3.8 percent in 2015 can be expected by the construction industry according to the official economic outlook of the *South African National Treasury* (Treasury, 2015). The National Development Plan (NDP) focuses on construction among others, as key focus areas, further highlighting the potential for growth in the construction industry.

From the presented evidence of major expenditure in this sector, it is clear that there exists adequate incentive for the construction industry to improve their supply management strategies and evaluate the effectiveness of current best practices and project management techniques in order to effect change within the industry. The potential savings from even a slight improvement in supply chain management efficiency would translate into billions (Love, Irani & Edwards, 2004). For example, an improvement of a mere two percent, that many critics may consider insignificant, when dealing with a project value of R20 billion translates into a significant saving to the client.

Many organisations rely on a cost effective supply chain just to survive in the market place whereas in the public sector there is always an increasing demand for savings in the supply and procurement processes, the same being true for the construction industry. According to *Michael Quayle*, "the globalisation of some sources of supply and a need to ensure local economic development make it essential that professional practice is improved and regarded as a key element in the preparation of company or organisational strategies" (Quayle, 2006). Simply put, the management of suppliers along with robust procurement and supply chain management strategies, is essential for a public sector organisation, the same being true for the construction industry. A possible management strategy for such companies may lie in the implementation of a SCOR model or a more specialised BSCOR model in order to improve construction logistics and performance measurements.

Politics of the South African Construction Industry

South Africa is among the youngest democracies in the world, a result of which is gender and racial inequality. After battling the discrimination and racial segregation that was apartheid, the country is in its 21st year of democracy (Scaruffi, 2014). However, the effects of apartheid are still felt in the construction industry, as is the case in all business sectors in the post-apartheid South Africa. In an attempt to redress the inequalities of the past, the South African government implemented the Black Economic Empowerment Act (BEE) that gives economic privilege to previously disadvantaged ethnic groups that was not previously allowed to them (The Department of Trade and Industry, 2012).
BEE legislation implemented measures that allowed preferential skills development, ownership, employment preference as well as preferential procurement to those groups of people that were previously disadvantaged. Companies were forced to employ a certain percentage of certain demographic groups, regardless of their qualifications or merit. As such, BEE has become one of the most contested terms in South Africa today (Southall, 2004). The idea behind BEE is to redistribute assets, wealth and economic opportunity in an effort to transform the economy of the country to be representative of the racial demographics and to promote economic growth. Those failing to abide by these regulations face jail time of up to ten years (Prinsloo, 2012).

Implemented in 2003 and plagued by corruption and dishonesty according to a comprehensive article authored by *Southall, t*he programme was criticised for benefiting only a few previously disadvantaged groups and was thus replaced in 2007 by a programme called Broad-Based Black Economic Empowerment (B-BBEE) (Southall, 2004). Where under BEE, only a few previously disadvantaged individuals benefited tremendously, the idea behind B-BBEE is to distribute wealth, not only to a few individuals but rather to a broad spectrum of previously disadvantaged members of society. In summation, in a period of roughly 15 years, black owned companies have grown exponentially and have become large players in the construction industry with about R600-billion been exchanged in BEE transactions since 1995 (Holmes, 2013). The fact of the matter unfortunately is that many (and some would argue the vast majority) of these companies are ill equipped to complete the jobs that they tender for. One of the many problems lies in the fact that this drive for economic parity and wealth distribution, be means of advantaging the previously disadvantaged and disadvantaging the previously advantaged, has led to a scenario where well-skilled individuals have been effectively forced out of their positions to make way for unskilled individuals under the BEE act, thus marginalising certain sectors and demographic groups out of the mainstream economy, according to *Prinsloo* (Prinsloo, 2012).

A prime example of BEE and affirmative action is highlighted by a proposal made by *Eskom* in the first quarter of 2015. In a public report, *Eskom* revealed plans to fire as many as 3389 skilled white-only employees, among them in excess of 1000 engineers as well as managers at various levels of management (BusinessTech, 2015; Prinsloo, 2012). This comes at a time where there is a undeniable energy crisis in the country, where in the first two months of 2015 the national energy utility was only able to produce electricity for the entire country 31% of the time over these two months (Tarrant, 2015). This is as a result of poor management and forecasting on the part of *Eskom* and the ANC government, which some might argue is due to the skills shortages within both Eskom and the South African government itself. Instead of cross-culture, cross demographic collaboration that will produce the most beneficial results for the South African economy, government is applying more stringent BEE rulings through pressure on industry to conform to affirmative action transformations (Holmes, 2013).

A typical medium-to-large company in South Africa, in order to comply with the economic empowerment act, will have a minimum black ownership and black management in the region of 20% and 10% respectively (The Department of Trade and Industry, 2012). These employees will often take the place of top level managers and CEO’s, despite not having the adequate qualifications, but rather qualifications in relatively “soft” areas such as marketing (Southall, 2004).

For example, former ANC Minister of Parliament and Minister of Communications *Pallo Jordan* claimed that he held a postgraduate doctorate degree, he in fact has not a single tertiary qualification. *Hlaudi Motsoeneng*, the SABC CEO claimed to have a matric qualification, a poor and completely inadequate qualification for any CEO to possess not only in South Africa but globally, albeit, findings show him to in fact not even have a valid matric pass.

Ill-equipped individuals have on occasion been promoted to positions that far exceed their capabilities, a result of both BEE and B-BBEE pressuring large companies and corporations to employ these individuals in positions of power for the sake social equality and to the detriment of economic growth and development (Nkomo, 2005). This “lack of management experience and skill” cannot be overlooked when it comes to budget overruns and schedule delays that can be attributed to poor management or poor execution of management initiatives.

According to an article published in the *Southern African Business Review*, BEE has a significant impact on ten dimensions, these include; overall domestic and global competitiveness, service excellence and client satisfaction, quality and acceptance of products and services, productivity, entrepreneurial spirit, production performance, human development and staff morale, business ethics, sales and access to markets, and financial performance (Krüger, 2011). The results were founded on a survey that achieved 500 responses from employees of all demographics. The respondents were all employed in small enterprises and micro-enterprises, medium enterprises or large multinational companies such as *Company A*.

According to the article, the majority of respondents agreed that BEE would not improve the performance of their company in any of the previously listed ten dimensions and from the results of the study it is clear that the adoption of BEE practices have little support from mangers in South Africa (Krüger, 2011).

The reality is, however, that when conducting business in South Africa companies need to realise that there are Corporate Social Responsibility (CSR) policies that need to be honoured and is something that companies need to keep in mind in order to ensure successful business (Alessandri, Black & Jackson, 2011). This will be a focus of the case study conducted at a later stage of this study, to attempt to implement structures and built in redundancies that will safeguard against poor decisions and limit the impact of ill-equipped decision makers within an organisation (Ngwenya, 2007).

2.3.2 Project Management

Much of the focus in the construction industry is centred on developing effective ways in which to incorporate and "marry" the concept of SCM with conventional project management practices. A typical supply chain in a project-based organisation such as a construction company will be similar to that illustrated in Figure 2-5.

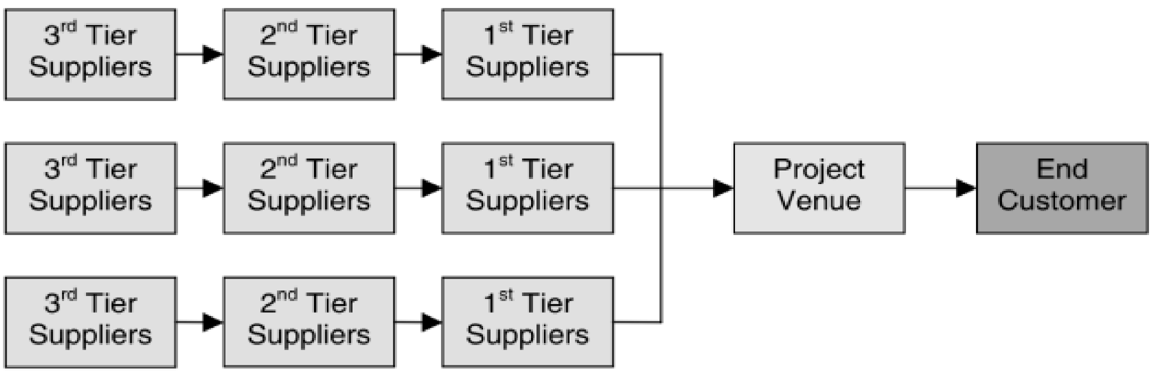


Figure 2-5: Project-based organisation's supply chain (Venkataraman, 2004)

Due to the fact that the supply chain of a project-based organisation is relatively complex, the role of project management is made more difficult. Consequently the process of integration between existing project management techniques and SCM techniques based on the SCOR model, is extremely challenging from a technical point of view. From a holistic point of view, integration is also challenging since many role-players that would not ordinarily interact, are required to collaborate with each other under a SCOR based approach, as opposed to operating autonomously, as would be the case in traditional projects.

Construction supply chains and projects as a whole comprise of a complex array of contractors and subcontractors, managing and integrating such a supply chain is a near-impossible task, requiring unprecedented collaboration and transparency on the part of all stakeholders. It involves a trade-off between individual interests of stakeholders and the global interests of the project as a whole in order to achieve value optimisation of the project, often at the expense of one or more individual interests. This is the very reason, coupled with a scepticism among contractors and subcontractors as to the merits of SCM that many believe is the root cause for the ill-management of supply chain in the construction industry (Venkataraman, 2004). Without project managers explicitly promoting joint collaboration among stakeholders, sub-optimisation will occur and the global goal of the project will not be realised, leading to budget overruns, schedule delays and ultimately project failure. Simple project management may often be the answer to poor performance in project supply chains, although simple SCM principles such as inventory management, value optimisation and collaboration have the potential to significantly improve SC performance and in turn reduce project life cycle costs. Project management techniques considered in previous studies include, but are not limited to: scenario analysis and forecasting, capital rationing, risk analysis, life-cycle-analysis, financial performance monitoring (NPV) and scheduling (Asrilhant, Meadows & Dyson, 2006).

Listed below in Table 2-6 are the most commonly used project management software's and their associated functionalities as listed by the respective software vendors. The characteristics listed in Table 2-6 are based on industry research and estimation, social media exposure as well as evaluation of professional reviews.

Table 2-6: Popular project management software and their functionality (Barrish, 2013)

Software Package		Functionality																		
	Est. # of users (In Thousands)	Cloud / Web / Mobile-Device Integration	Budget Management	Bug Tracking	Collaboration	Email Integration	File Sharing	Gantt Charts	Idea Management	Issue Management	Milestone Tracking	Percent-Complete tracking	Portfolio Management	Project Planning	Requirement Management	Resource Management	Status Tracking	Task Management	Testing / QA Management	Time and Expense Tracking
Microsoft Project	22'000	X	X		X			X			X									
Atlassian JIRA	30'000	X				X	X			X	X	X		X	X				X	
Podio	1'000	X		X	X		X		X	X	X		X	X			X	X		X
Smartsheet	1'500	X	X		X	X	X	X		X	X	X		X		X	X	X		X
Basecamp	15'000	X			X	X	X				X							X		
Teamwork PM	1'500	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Version One	1'250	X			X	X	X			X	X	X	X	X	X			X		
Assembla	800	X			X					X			X					X		
Mavenlink	750	X	X		X	X	X	X		X	X	X	X	X		X		X		X
Project Manager	340	X	X		X	X	X	X		X	X	X	X	X	X	X		X		X
Asana	400	X			X		X		X	X	X			X			X	X		
Freedcamp (FREE)	396	X			X	X	X			X	X			X				X		X
Zoho Projects	1'200	X			X	X	X	X		X	X			X				X		X
Central Desktop	650	X			X	X	X				X	X		X	X	X		X		X
Teambox	600																			
Wrike	1'000	X		X	X	X	X	X		X	X	X	X	X		X	X	X		
Trello	300	X	X	X	X	X	X		X	X	X			X		X		X	X	
Intervals	200	X	X	X	X	X	X	X		X	X	X		X		X	X	X	X	X
Planbox Project Management	75	X			X	X	X			X	X	X	X	X	X	X		X		X
Redbooth	600	X		X	X	X	X	X			X			X	X	X	X	X		X

The vast majority of projects in South Africa are managed by rudimentary software packages, mainly using *Microsoft Project* despite the fact that there exist various other software packages that provide more functionality, as presented in Table 2-6 (Barrish, 2013). Large projects could benefit significantly from the implementation of more capable, less rudimentary project management software's such as *Teamwork PM* or *Project manager,* to name a few. Such packages incorporate many more features than that found in MS Project for instance, allowing the user to exploit such functionality in a useful manner, ultimately benefiting the project. The ability of a software to measure and monitor KPI's such as percent complete as well as providing a platform for bug tracking, email integration, cloud-based services and time and expense tracking allows the user to make more informed decisions and ultimately manage the project more effectively.

It has become an industry trend within South Africa to, by default, use Microsoft project as a project management software, regardless of the specific requirements and intricacies of the project at hand. This culture of blind acceptance can be a key factor in the success or failure of a project, the selection of a project management software is crucial to the successful management of the project (Albert, Chan, Scott, Ada & Chan, 2004).

Another challenging aspect to successfully managing a project is the identification and implementation of an adequate planning and or design model. Similar to the selection of a project management software package, each project has a core consideration or scope, the successful management of which needs to be considered as a critical success factor. Table 2-7 lists various scenarios where such a model may prove useful, its application, scope and methodology.

Table 2-7: Project management planning and design models and applications
(Sarker, Egbelu, Liao & Yu, 2012)

Planning and design perspectives	Application perspectives		Modelling perspectives	
	Scope	Applications Modelling	Model Type	Methodology
Scheduling and Dispatching	Dispatching space	Truck Routing	Supply chain, time minimization and resource levelling	Algorithms
Resource allocation and levelling	All projects	Equipment and manpower	Scheduling and resource levelling	Mathematical programming
Buffer Stocks	Project sites & procurement	WIP, work flow reduction, cycle time	Inventory, storage, flow balance, cost minimization	Integer
Production and inspection	Project sites & procurement	Work-in-process, cycle time	Just-in-time, cost and time minimisation	Optimisation
Linear Projects	Road Construction	Scheduling, traverse operations, cost estimation, risk management	Cost minimisation & resource planning	Project management

Time and Cost Estimation	All projects	Risk management	Time and cost minimization	Mathematical modelling
Infrastructure	Public projects, bridge and road construction	Cost escalation factor	Cost and time based models	Project management
Contractor and subcontractors	All projects	Profit sharing and labour cost	Profit maximization, contractor minimization	Optimisation
Material Delivery	Project sites	Delay, delivery time, demand variation ratio	Cost minimisation, space minimisation	Optimisation

From models such as those presented in Table 2-7, project managers are able to formulate a list of factors that affect the success or failure of a project. Formulated from many iterations of empirical research, there are essentially five main categories of factors: project related, procurement related, project management related, project participant related and external factors.

Authors *Chan* and *Scott* came to the conclusion that project success can be measured as a function of these success factors listed above. They also concluded that a project will be executed more successfully when the project complexity is low, when the project duration is short, when management actions are effective, when the funding of the project is handled by a private and/or experienced client, if the project brief is comprehensive, if decisions are decisive, if there are experienced project team leaders and when technology is used innovatively within the project in order to modernise the construction industry (Albert et al., 2004).

Based on this premise, a conceptual framework was developed by *Chan* in order to more successfully implement project management methods and ultimately achieve project success. This framework is presented in Figure 2-6. When executing successful project management, each and every one of these "success factors" needs to be focused on, by all members of both the management and construction team.

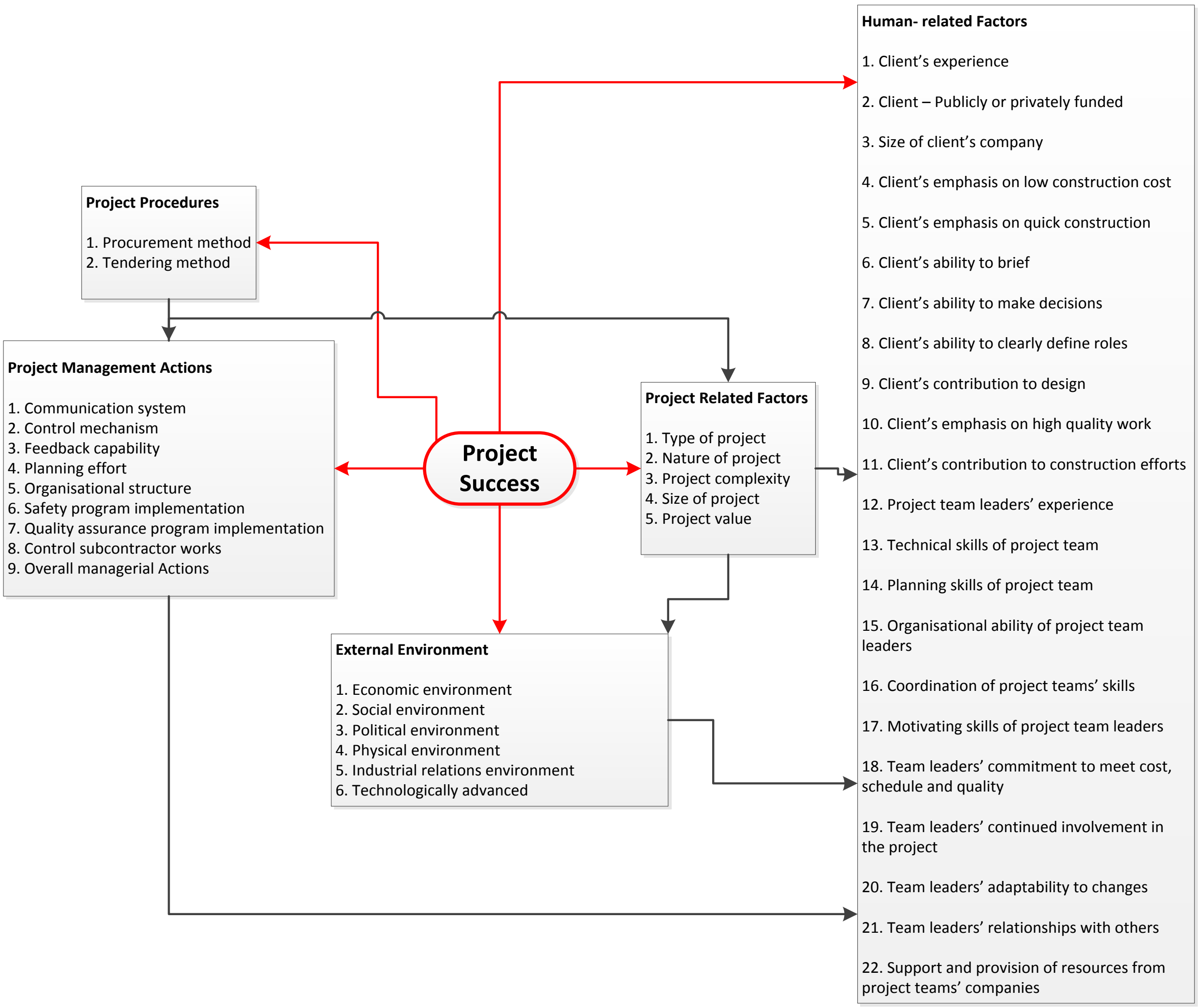


Figure 2-6: Framework of factors affecting success in projects (Albert et al., 2004)

Thus, successful project management is a balance between combinations of project management actions, project related factors and human related factors, external factors such as the economy, specific project management models and project management software.
These factors are all closely linked as illustrated in Figure 2-6 and all form part of the overall success of a project, one cannot be considered without considering the others as they all form part of project success. Successful project management requires specific consideration of all these factors and does not simply entail selecting and using an arbitrary software package.

2.4 Supply Chain in the Construction Industry

There are two main reasons for the interest in construction supply chains: lagging productivity development and increased economic importance of the SC (Vrijhoef & Koskela, 2000). Although relatively limited studies have been conducted in the field of construction SCM, it is suggested that poor supply chain design can and often does increase project cost by ten percent (if not more) and when dealing with budgets in the hundreds of millions and even billions of rands, this increase in cost of ten percent can be extremely significant (O'Brien, 1998). Traditional approaches are no longer effective in maintaining control of construction supply chains, calling for a shift toward more effective SCM initiatives. According to various authors, since the late 1990's, many academics and industry orientated specialists have tried to merge the idea of a supply chain management theory with the construction industry in an attempt to understand and characterize the coordination of sub-contractors and suppliers in a typical supply chain (Segerstedt & Olofsson, 2010). Since the production of subcontractor and suppliers traditionally form the largest proportion of project costs (O'Brien, 1998), SCM approaches may have similar benefits to the construction industry as those experienced in the manufacturing sectors where SCM is common practice. Many construction supply chains are described as being "loosely coupled supply chains" (CIPS, 2002). This infers that cutting-edge businesses, the industry trail-blazers, are moving away from their traditionally tightly coupled processes and are instead opting for loosely coupled ones, making themselves not only more flexible but also more profitable (CIPS, 2002). This said, such an approach towards supply chain management involves assessing the benefits to be gained through better utilisation of resources from outside the restrictions of a company by, for example, partnering with certain suppliers or strategic contractors. This could lead to more integrated supply chains that take advantage of collaborative agreements between clients, suppliers and contractors by placing emphasis on the importance of the role of strategic suppliers in the overall functionality of the SC (Dubois & Gadde, 2000).

A summary of the research conducted on the implementation of supply chain management in the construction industry is provided in Table 2-8.

Table 2-8: Summary of literature on Supply Chain Management in construction

Literature Title	Author	Focus Area
The changing role of builder's merchants in the construction supply chain.	Agapiou, A., Flanagan, R., Norman, G. and Notman, D. (1998)	Regarding "building merchants", the suppliers of the building industry, as key players in the construction supply chain.
Client-led strategies for construction supply chain improvement.	Briscoe, G.H., Dainty, A.R.J., Millett, S.J. and Neale, R.H. (2004)	The importance of the client within the supply chain.
Strategic Procurement in Construction.	Cox, A, Ireland, P, Townsend, M (2009)	The relationship between SCM and market structure.

The construction industry as a loosely coupled system: implications for productivity and innovation.	Dubois, A. and Gadde, L.-E. (2002)	A more integrated supply chain using collaborative agreements between suppliers, contractors and clients.
Mapping construction supply chains: widening the traditional perspective of the industry.	London, K. and Kenley, R. (2000)	Client organisation as the focal point in a supply chain model from an industrial organisation perspective.
Supply chain integration for achieving best value for construction clients: client-driven versus supplier-driven integration.	Vrijhoef, R. and de Ridder, H. (2005)	Supply-driven and client driven integration strategies in a model of supply chain structure, as seen from an industrial organisation's perspective.
The four roles of supply chain management in construction.	Vrijhoef, R. and Koskela, L. (2000)	Explanations for root causes of low productivity development.
Construction Supply Chain Management: A vision for advanced coordination, costing and control.	Dr. William J O'Brien (1998)	Construction supply chain management adoption in order to improve costing, coordination and control.

2.4.1 The Construction Industry Supply Chain

The construction industry is one of the largest employers of both unskilled and semi-skilled workers in South Africa. According to the official *Quarterly Labour Force Survey* of 2014, construction provided direct employment to 1.149 million people (5th largest by industry) while the mining sector employed approximately 419 000 (Statistics South Africa, 2014). The construction industry's market structure is generally make-to-order as opposed to the manufacturing industry's standardised make-to-stock and occasionally make-to-order market structure.

Manufacturing a product usually entails no more than 3 000 components (motor vehicles) whereas construction of buildings and infrastructure entails around 40 000 components with a project duration of anywhere between 4 to 40 months (project dependent). Certain projects can extend up to a period of 25 years in instances where a build-operate-transfer (BOT) contract is in place, whilst manufacturing's production time is often hours. Different contracting models that are commonly used in the South African construction industry are further expanded on in section 0.

Key industry features of the construction and manufacturing industries are listed in Table 2-9, both problems and unique attributes.

Table 2-9: Industry characteristics comparison

	Construction	Manufacturing
Key industry characteristics and problems	Fixed locations	Fixed locations
	Temporary, independent multi-organisations	Repetitive, continuous production facilities
	Short-term relationships	Focus on continuous improvement and rapid prototyping
	Iterative , overlapping processes	Innovative production facilities
	Local markets	Innovative procurement methods
	Prototype products	Continuous processes and relationships
	Distinct process of production	Highly modularised components
	Many role-players, up to 90% of them sub-contractors	Standardised parts
	Many customers and suppliers	Highly competitive global markets
	Temporary locations	Extensive use of JIT, lean and agile supply chain methodologies, tools, technologies and concepts
	Low inter-dependency	
	Lack of trust	
	Low barriers to entry	
	Lack of research ,development and innovation	
	Highly complex processes	

Modern day construction is a cutting edge industry consisting of well educated, well managed individuals working in collaboration with one another in a structured manner. Construction is no longer only site based either; modern site construction is a combination of fabrication and assembly, all meticulously planned and managed.

Industrialization initiatives are at the forefront of modern construction, simplifying site construction to only final assembly and testing, in an effort to reallocate as much work as possible from the site to the "shop" where it can be managed more effectively and executed more efficiently. Final assembly will always be done on site, since construction is a site-production industry, although the degree of work will differ with the stage of development and the specific project being "assembled". Planning and control are considered to be among the critical success factors that need to be correctly implemented in order to achieve efficient site assembly. Table 2-10 expresses the twenty most common project management critical success factors identified by *Azim*, who evaluated 63 publications in order to identify critical success factors most commonly cited in literature.

Table 2-10: Critical success factors of construction projects (Azim, 2010)

Critical Success Factor	Number of Citations
1. Support from senior management	39
2. Clear realistic objectives	31
3. Strong/detailed plan that is kept to date	29
4. Good communication & feedback	27
5. User/client involvement	24
6. Skilled/suitably qualified/sufficient staff/team	20
7. Competent project manager	19
8. Strong business case/sound basis for project	19
9. Sufficient/well allocated resources	16
10. Effective Leadership	16
11. Proven/familiar technology	15
12. Realistic schedule	14
13. Risk addressed/assessed/managed	14
14. Project sponsor/champion	13
15. Effective monitoring / control	12
16. Adequate budget	12
17. Organisational adaptation/culture/structure	11
18. Good performance by suppliers/contractors/consultants	10
19. Planned close down/review/acceptance of possible failure	10
20. Project size (large)/level of complexity (high)/number of people involved /duration over 3 years	4

For the purposes of this study, Project Success is defined as; "The project meets the technical performance specifications and/or mission to be performed, and if there is a high level of satisfaction concerning the project outcome among key people on the project team, and the key users or clientele of the project effort" (Albert et al., 2004) while Critical Success Factors are defined as being; "Factors which, if addressed, will significantly improve the chances for successful implementation" (Tavallaei, Hosseinalipour & Mohebifar, 2015).

When having a discussion relating to the construction industry, it is not unusual to hear that the construction industry differs completely from other industries on both an organisational and strategic level. Due to this apparent misalignment between the construction industry and other industry, such as manufacturing, conventional solutions to industrial and production problems are not directly applicable and other solutions and concepts for improving performance and efficiency need to be evaluated (Segerstedt & Olofsson, 2010). When evaluating Table 2-10, however, one can but help to notice that the critical success factors that are mentioned are not unique to the project or construction environment. Many of the listed success factors are precisely what would be found in a manufacturing environment such as in a pharmaceutical factory.

Construction: The role of subcontractors and suppliers

A construction project is not simply an individually focused effort where a single contractor is responsible of the execution of a particular task such as what is traditionally encountered in a production based industry. Rather, it is a combination of a client, principle contractor, sub-contractors and their sub-contractors. O'Brien classifies a construction site as being a constantly changing environment, with specific dynamic conditions that characterise the modern day construction project (O'Brien, 1998) and speculates that this set of conditions provides a rational basis for the improvement of both control and coordination of such projects. In a typical construction project, the principal construction contractor or an appointed consultant will manage the project and will, in general, perform only a small part of the "product" by means of its own resources and employees, while the bulk of the work, up to as much as 90% (Dubois & Gadde, 2000), will be outsourced to specialised suppliers and subcontractors, managed and coordinated by the consultant or principle contractor.

Since many of the theories applied in SCM are borrowed from other areas of management, such as accounting and engineering to name just a few, construction supply management (CSM) is a type of hybrid management methodology. The vast majority of the theories currently applied by SCM have existed for a decades, some older than the concept of SCM such as: Transaction Cost Economics Theory, Network Perspective, Social Network Theory, Resource Based View, Principle-Agent Theory, Game Theory, Systems Theory and Strategic Choice Theory (Spina, Caniato, Luzzini & Ronchi, 2013; Day & Lichtenstein, 2006). These theories are mentioned for the sake of completeness and will not be discussed further in this study although each of the mentioned theories have a different role to play in management and structuring of a SC and so each provides a distinctive viewpoint of supply chain management. As a result, there exists no single cohesive theory for SCM. Rather than a single global definition for what SCM is, the management of the supply chain is dispersed into four subsections; Operational SCM, Strategic SCM, Organisational SCM and Project Specific SCM (Pala, 2014).

Depending on the type, nature and sourcing policies of a project, most construction projects follow linear or concurrent phases of brief, design, procure, construct and operate. This is different to that of the manufacturing industry, principally due to the role of the subcontractor in the construction context.

Since most construction projects are run by a single contractor, the number of suppliers involved at each phase depends on that main contractor's ability to source them, the general industry trend being that internal supplier sourcing accounts for a mere 10% of the project's activities. This means that as much as 90% of the project's associated work is outsourced to one or more subcontractors, often a specialised, highly skilled artisan or specialised suppliers. One of the main concerns of the main contractor is to manage the relationships with suppliers and identify the key and/or critical suppliers that are essential in successful project execution. By actively monitoring the relationships with strategic suppliers and subcontractors, the main contractor reduces the risk of budget overruns and delays to schedules, and by doing so the main contractor encourages each subcontractor and supplier to effectively manage their relevant suppliers and subcontractors more effectively. This is ultimately to the benefit of all collaborators involved in the project and collaboration among stakeholders is among the key principles that drive successful SCM. For this reason the importance of these interactions and relationships cannot be understated.

SCM in the construction industry is complex since there exists many intertwined connections between firms, projects, markets and technologies, more than that found in the manufacturing industry. The large number of variables and unknowns of a construction project make it extremely challenging to map the interactions between the many role-players in the SC (Pala, 2013). The degree to which suppliers and subcontractors are involved in on-site activities varies depending on the type of construction and contractual model employed on the specific site. It is however not uncommon for the number of project stakeholders to increase as the project construction stage is being executed, due to the fact that many processes are being executed simultaneously and concurrently. Once the construction stage is complete, fewer suppliers and contractors will engage with the operations or facilities management of the project (Pala, 2014). A typical procurement and materials delivery management process, incorporating subcontractors and suppliers is as illustrated in Figure 2-7.

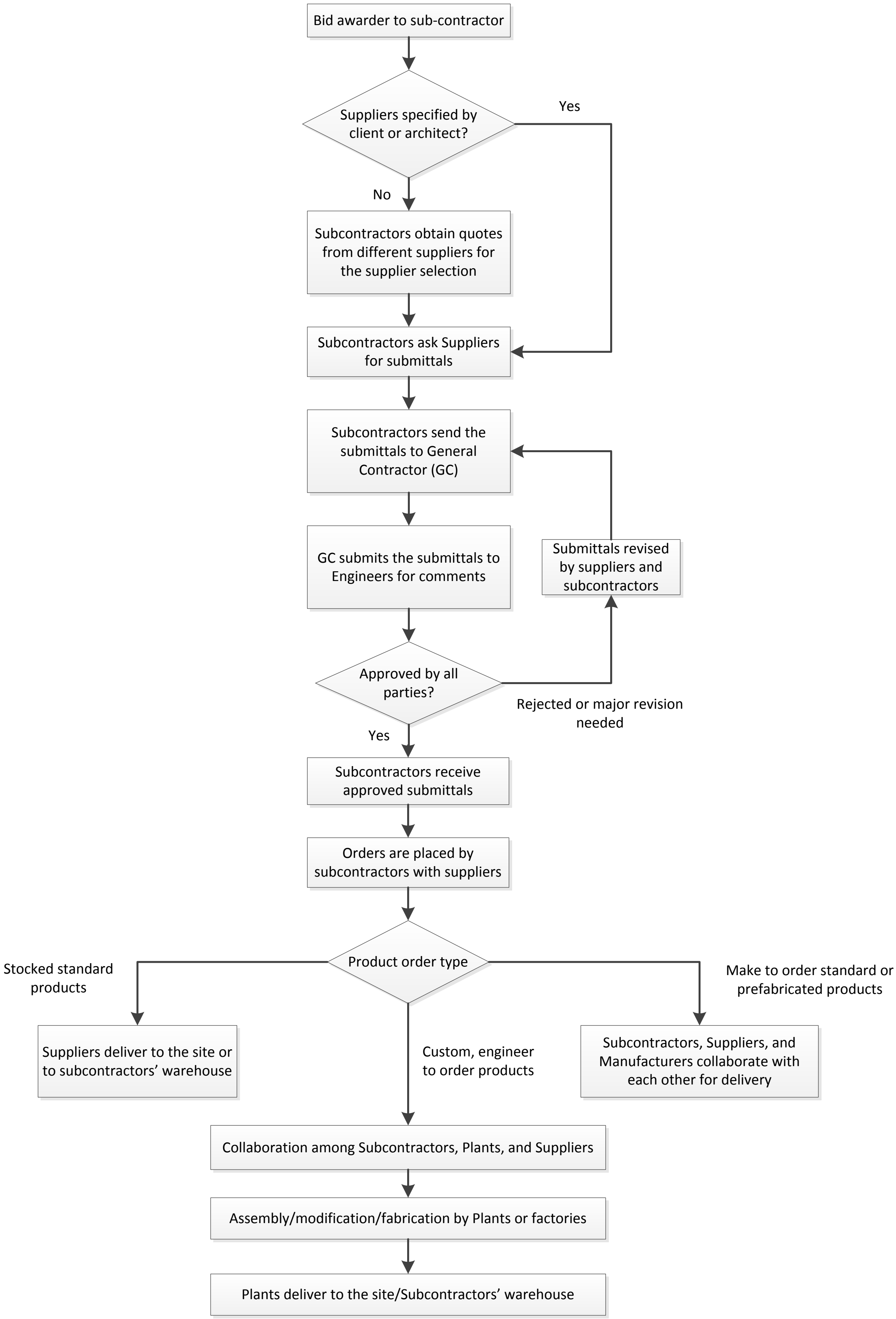


Figure 2-7: Procurement process of a typical construction project Adapted:(Cheng, Kincho, Bjornsson & Jones, 2010; Naoum & Egbu, 2015; Caron, Marchet & Perego, 1998)

Construction supply chain management in comparison to that of manufacturing

In the past, most efforts to define and improve the supply chain in the construction industry were focused on the elimination of the abovementioned idiosyncrasies, by implementations of production-based ideals such as site production by means of industrialization and engineer-to-order products by means of pre-engineering, such as pre-fabrication.

Authors such as *Love and Edwards* suggest the adaptation of lean principles for the construction industry, arguing that parts and components of a construction project more similar to manufacturing, should implement lean techniques developed in manufacturing and techniques suitable for the idiosyncrasies of the construction industry should be established to “minimize the peculiarities in construction”(Love et al., 2004). Lean thinking, a book authored by *Womack* also suggests that a lean approach to construction will improve the sector (Weigel, 2000).

The construction industry undoubtedly differs from a conventional production industry due to the various idiosyncrasies of construction such as one-of-a-kind “engineer-to-order” products as discussed earlier. The formation of temporary-management-organizations and in-situ site constructions constrain the development of efficient and effective material and information flows, such as those traditionally attained in a manufacturing environment (Vrijhoef & Koskela, 2000). Construction can also be viewed as unique, since factors such as soil conditions, wind loads, seismic conditions and environmental legislation are regularly changing.

In the South African context, all construction activities are governed and regulated by the South African National Standards (SANS), a statutory body that governs all national standardisation in South Africa (SABS, 2012). Even under the governance of the SANS standards, construction is said to fall into a “fixed position manufacturing” category, much like shipbuilders; differentiated primarily by the fact that production is localised to a specific site and workers move through the product instead of the product moving through a factory. Site production also occurs in industries such as mining and agriculture, emphasising the fact that “projectization” is not an industry-bound phenomenon (Ballard & Howell, 1998). Ways in which industry can limit the uniqueness of construction is by standardising components used in the construction process, adopting prefabrication over in-situ, using modularisation and by maintaining consistency in project team composition and operation. This topic will later be discussed in more detail. These characteristics are at the centre of the debate as to whether the construction industry is in fact so different from manufacturing, where it is argued that technology transfer and adaptation from fields such as manufacturing and production is simply not possible.

One example where a construction project can be directly compared to manufacturing is in the case of a continuous construction, such as a tower construction. Most often found in scenarios where there are major concrete works and where the structure under construction is not complex in nature, for example, a constant diameter tower. This type of construction is a continuous process of concreting and reinforcing as well as the associated processes that accompany such a process such as aggregate crushing, material logistics, etc. Climbing formwork is a unique type of formwork used in the construction of large vertical concrete structures, such as a tower where the structure requires seamless walls and the form is very repetitive (Aboutmoney, n.d.).

Figure 2-8: Slip-form construction for uniformly shaped structures (Max Bogl, 2015)

A true continuous construction process will make use of a gliding formwork, known as *Slip-form* as illustrated in Figure 2-8, a continually climbing structure that is moved at a constant speed by hydraulics and a series of steel members. When drawing parallels to manufacturing, this *Slip-form* could essentially be seen as the "factory warehouse" around which all the production takes place.

The formwork of a bridge pier is another good example of a *Slip-form* and is illustrated in Figure 2-9. This structure is propelled continually and the concreting and reinforcing activities take place around motion of the "factory". The rate of production is directly proportional to both the rate-of-climb and material requirements of the specific section. Trucks, cranes and sometimes trains transport material to the site while cranes and concrete pumps transport material within the site, whilst people and machines carry out the actual physical work, similar to the production lines that are common in mass production in the manufacturing industry.

Figure 2-9: Complex slip-form used to construct a no-uniform structure

Frequently certain components used in the construction process are prefabricated off-site and then transported and installed as complete components. Such methods of standardisation and prefabrication are essential in achieving a manufacturing production-like environment, where simplification of a complex product leads to improved productivity and quality. It is with this type of innovation that the construction industry can modernise its approach to management, without changing the way in which management is conducted. By simply adopting manufacturing-type processes, the management of those processes shall be improved due to the nature of the process, instead of the manner in which that process is managed. This is the type of SCM that could potentially revolutionise the construction industry. The potential could thus lie in the selection of processes instead of the restructuring of businesses and complete overhaul of their management structures.

Other authors argue that a complete manufacturing approach to the management and process selection of construction activities needs to evaluate just what kind of production a construction site is. This needs to be taken into consideration when adopting manufacturing management techniques.

In order to demonstrate the potential that lies in the adoption of prefabrication, an example is presented that is of relevance in the South African context. According to the NDP, government has committed to providing tens of thousands of new houses to rural communities throughout South Africa (Treasury, 2015) at a cost of billions of rands. In December of 2014, Human Settlement Minister, Lindiwe Sisulu announced that government planned to build 1.5 million low cost houses in the following five years (Vermulen, 2014). The budget for each of the five years was announced to be R34 billion, totalling to an amount in the region of R170 billion that is planned to be separated into various mega projects throughout the country.

If the concept of prefabrication was to be adopted in such mega-projects, the potential for improving quality, productivity and service level agreements is vast and will directly translate to cost savings as well as improved budget adherence (Greyling, 2009). As discussed earlier, there are significant time and cost savings on projects that implement prefabrication construction techniques, especially for construction that is repetitive, as is the case with low cost housing. All low cost houses are built to a specific standard, which is standardised countrywide and thus facilitates the implementation of prefabrication construction techniques.

The construction supply chain can be described, from a high level point of view, as illustrated in Figure 2-10. This SC comprises the end-customer, labour, contractors and subcontractors as well as materials and equipment suppliers. Figure 2-10 provides a brief description of the interaction between each role player in the SC as well as a short summary of their associated responsibilities and expectations.

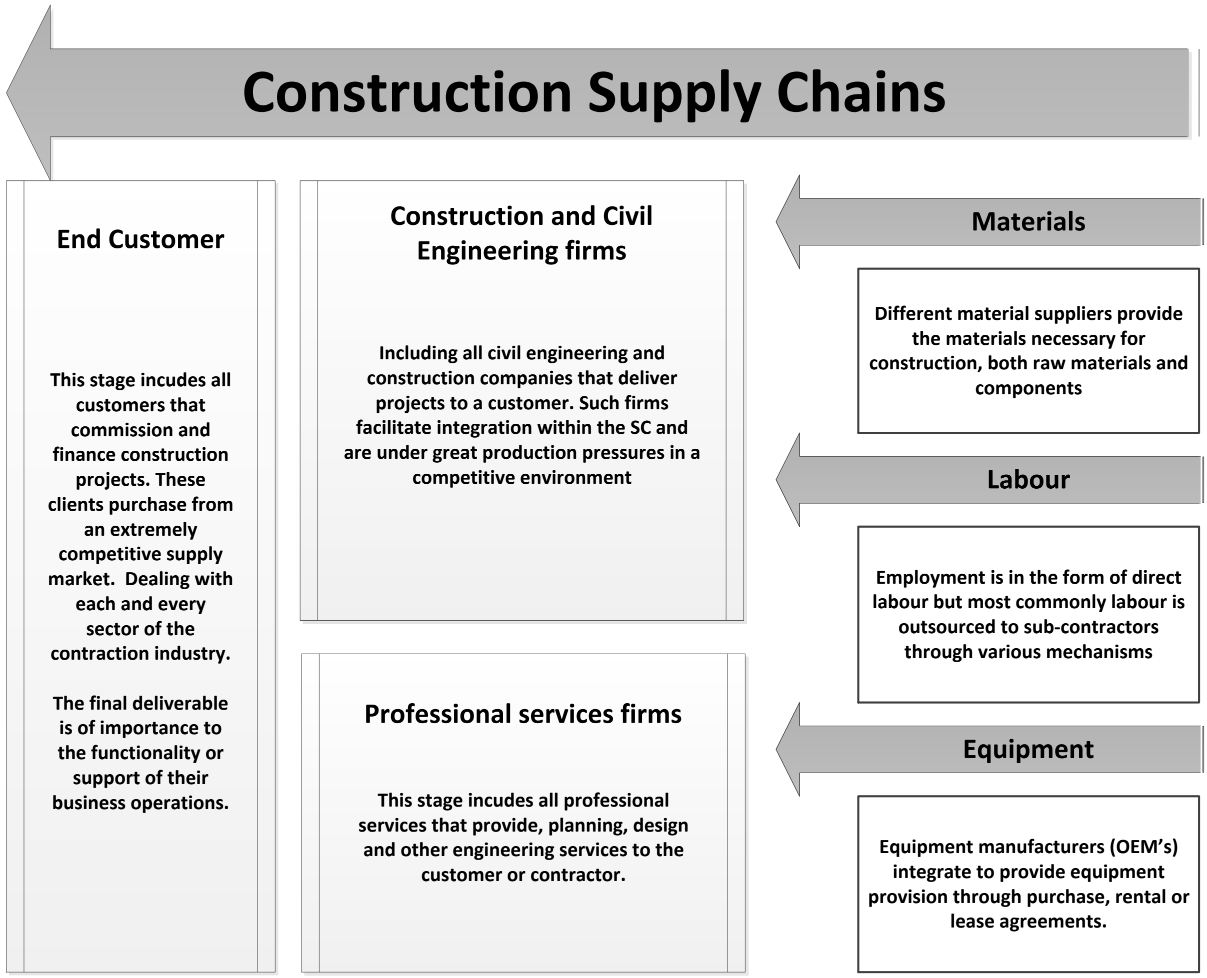


Figure 2-10: The Construction Supply Chain (Cox, Ireland & Townsend, 2009; Thunberg, 2013)

2.4.2 What Type of Manufacturing is Construction

As described in the preceding section, a clear "line in the sand" needs to be drawn between what kind of production the activities associated with construction are. Without this differentiation between which activities are like and unlike manufacturing, many authors such as *Sarker* and *Winch* suggest that it is impossible to apply the principles of manufacturing, such a lean (Sarker et al., 2012; Winch, 2003). They suggest that there must exist sufficient similarity between a construction project and a type of production before there can be any benefits from adopting manufacturing-type principles, such as lean (Ballard & Howell, 1998).

Ballard and *Howell* suggest that it is in fact possible to apply the principles of manufacturing to the areas of construction, even if these are profoundly different to those of manufacturing. The fact that the production output of a construction project is of an immovable nature prompts critics to believe that the relationships between supply and production, client and customer as well as contractor and subcontractor differ considerably from that of traditional factory-based production. It is such thinking that forms the foundation for the argument that construction cannot be directly likened to production.

Categorizing various types of manufacturing

When categorizing a manufacturing process as a certain production, there are three main categorization criteria. The method first makes use of a matrix of variables in order to classify just what type of manufacturing is in question, making use of product mix and the pattern of processes involved in the manufacture of the product. Another method uses the principal determinant of flow throughout the process, while another classifies all fixed position manufacturing. These are special permutations to conventional manufacturing such as aircraft and ship manufacturing, as well as construction (Liu & Wang, 2011). These distinctions are based on either product or process flows. Construction, however, can be classified as a combination of the two. Since the construction process of a concrete structure is generally tightly coupled, this means work that is made available to a downstream team or department is made available by the upstream team or department, this is known as a series process manufacturing configuration. However, the installation of a pipeline and a pump-station does not necessarily need to be of a series nature, but rather is a parallel, loosely coupled set of activities, that operate independently to one another.

Production can essentially be categorised into four main brackets, namely; *Once-off Production*, *Batch Production*, *Mass Production* and *Continuous Production*. Construction is generally considered to be a once-off production, such as a dam or an intricate structure such as a bridge.

One of the many problems that face the construction industry is that all projects are seen to be once-off-productions, when in fact there exists sufficient evidence to suggest that there are permutations in specific projects, where batch production and even mass production occur. For instance, when there is a project to construct 10 000 low-cost houses, all of the same material and size, one could argue that this is in fact a batch production instead of a once-off-production. When considering a specific aspect of a construction, for instance the fabrication of tunnel support struts, one could argue that there is an element of mass production at work. The tunnel sections that need to be constructed are of the same diameter and length, made to the same specifications with the same material. The construction of these individual sections may take place on-site but the principle of mass production remains intact. There exists a certain predetermined amount of reinforcing steel, concrete, formwork, etc. that is required to fabricate a section of tunnel and this fabrication is conducted in a certain manner, to certain specifications, and nothing changes. The only factor that differs in the previous example to a factory-type production is that there exists many more variables, such as soil conditions and weather, to name a few.

Thus it can be concluded that certain so called once-off-productions, are in fact just a permutation of a mass production system or at the very least, contain instances of known production systems that have been optimized in the manufacturing industry. If this is the case, tried and tested manufacturing systems and principles can be implemented in the construction industry in order to improve the performance of certain key processes that traditional project management continuously fails to improve. The question then remains, is construction really unique to manufacturing, and if so, how?

A key feature of manufacturing is that activities are carried out in a controlled and isolated environment, unlike a construction site that is exposed to the elements and often covers a large area. Construction is a combination of assembly production and fabrication production, with final assembly always taking place on site. With any on-site assembly, or assembly production line for that matter, the coordination of critical path flows through effective planning and control measures is critical for the efficient and streamlined operation of that process. Critical path activities and processes need specific attention in order to be executed as efficiently as possible, in turn costing as little as possible whilst employing as few man hours as possible. In order to transform construction to industrial activities, as many of the activities involved in the construction process need to be executed off-site in a controlled factory-like environment, simplifying the actual on-site construction processes to final assembly and commissioning.

If one is to consider the construction of a hospital for instance, it is clear that there are more challenges that face the construction industry than simply fabrication and assembly. Effectively, the construction process, if one can call it that, begins from the moment the city council decides to construct a new hospital, unlike a factory-type of manufacturing where a factory is contracted to produce a certain product without prior knowledge of the product being produced. In construction, the involved parties participate in the feasibility and design phases of the project all the way to project hand-over and even operation of the completed facility in a cradle-to-grave type involvement such as a BOT or BOOT contract (Doloi, Sawhney, Iyer & Rentala, 2012; Ofori et al., 1996; Segerstedt & Olofsson, 2010).

Projects consist of five distinct “basic phases” as per the Project Management Institute (PMI) (Project-Insight, 2015):

- Project conception and initiation
    - An evaluation of an idea on a conceptual and financial basis is conducted to evaluate project feasibility.
- Project definition and planning
    - A team is set up to draw up a project plan and scope, that is used a a guideline for the work that needs to be performed throught the project. The budget and schedule as well as resource requirements are developed; an extremely important step in the project, as this forms the basis of all further budgeting and scheduling efforts.
- Project launch or execution
    - Responsibility is delegated to subcontractors and teams for execution.
- Project performance and control
    - Project managers and key stakeholders compare project budget and progress to a master plan to evalute and control progress of the project.

- Project close
    - After the completion of all the activities relating to the project, a post-mortem report in compiled, highlighting the lessons learnt throughout the project in an effort to determine the success or failure of the project, based on KPI's such as budget, quality and schedule adherence.

Similarly, construction consists of three distinct "overarching-phases" that encompass the five "basic phases" discussed earlier: the pre-project phase, pre-construction phase, the construction phase and finally the post-construction phase. There are a vast array of feasibility, social and operational studies conducted by the contracted team in order to assess the financial and socio economic benefit of the proposed construction. Environmental impact assessments (EIA) also form a large part of the pre-project phase. These various phases have been condensed and arranged into ten "key phases" as shown in Figure 2-11 .

The manufacturing process protocol model

Figure 2-11 presents the inter-relationships between the previously discussed four "overarching-phases", "basic phases" and "key phases" showing the boundaries, either soft or hard that exist between each phase. Figure 2-11 is the product of the research conducted by *Aouad* and *Cooper* into developing a *process protocol model*.

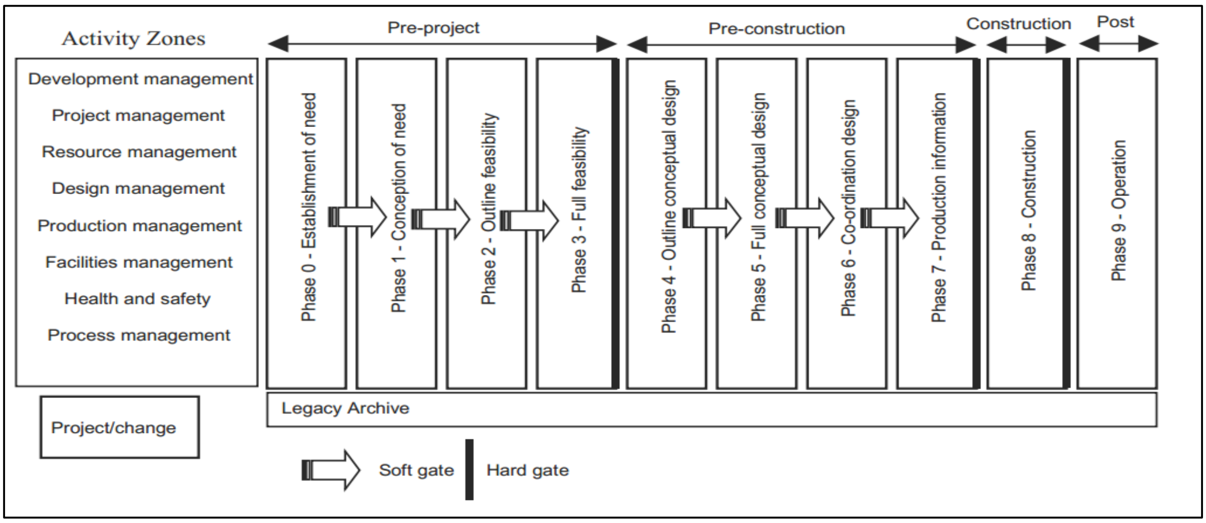


Figure 2-11: Construction protocol (Aouad, Hinks, Cooper, Sheath, Kagioglou & Sexton, n.d.)

Unlike a manufacturing project, a construction project, as previously discussed, involves the key stakeholders from the earliest phase of the project. This is cited by many authors as a main contributing factor behind many of the management complexities that face the construction industry of today and of the future (Van Heerden, 2013a; Monczka, Handfield, Giunipero & Patterson, 2009; Huemer, 2006; Rudberg et al., 2013; Quayle, 2006).

With regards to the model, the pre-project phases relates to strategic business considerations that translate to project feasibility and necessity. The outcome of this phase will be to obtain financial authority to proceed to the pre-construction Phase by means of systematic investigation and scrutiny of both the client needs and market conditions. This stage of a project is given limited attention, when compared to the latter stages of the project, odd considering the vast knowledge and insight the project could gain through collaboration and consultation with key stakeholders at early stages in the construction process. This concept of collaboration is once again highlighted as being a key driver of successful SCM. Failure to collaborate with stakeholders at the early stages of a project often leads to poor performance of the latter project stages, since the planning phase was poorly executed (Thunberg, 2013).

The knock on effect of poor Pre-Project Phase execution will affect the Pre-Construction Stage, where the client's needs are discussed and developed into an adequate design solution (G. Aouad, R. Cooper, n.d.). The Construction Phase is where the proposed processes are implemented and the conceptual solution is made a reality. It is in this stage where the true value of coordination and communication in earlier phases is evident and beneficial. If the pre-project and pre-construction phases were adequately executed, most changes in the client's requirements will be slight, a serious benefit to the budget and schedule adherence of the project, since there exists a definite increase in the cost-of-change as the construction process advances into the latter stages.

After construction has been completed, the process protocol continues into the final phase of the project, the Post- Construction Phase. The "sub-phases' within this phase serve as a tool to constantly monitor and manage the maintenance requirements of the constructed facility as it is commissioned and utilised.

Essentially, the construction process protocol is very similar to many of the existing protocols that are in use in the field of manufacturing. The field of New Product Development (NPD) research that stems from the manufacturing research field is an example of this. This field is concerned with the investigation of the challenges surrounding the development of new (once-off) products, similar to the pre-project phase of a traditional construction process. A NPD is essentially what each construction project is, a combination of a set of new and conventional requirements, challenges, variables and constraints.

A study conducted by *Aouad* and *Cooper* indicated that there exists distinct variations in the involvement of designer and assembler with regards to process involvement when looking at the NPD process in manufacturing. Similar to construction, where designers, contractors and other key stakeholders are involved from the start of the project, as discussed earlier, the manufacturing industry shows similar trends when looking at NPD. It seemed to be common for product developers to be actively involved in the requirements capture phase of a new product prior to commencement of the project (G. Aouad, R. Cooper, n.d.). This trend shows a distinct similarity to project based organisations' product development processes like those regularly encountered in the construction industry.

Coming to the point, what kind of supply chain is the construction supply chain? Authors *Vrijhoef and Koskela* delved into the roles of SCM within the construction industry and characterized some key elements of the supply chain, as listed below (Vrijhoef & Koskela, 2000) :

- The SC is converging in nature where a "construction factory" is set up around a specific product and then that single product is built from incoming materials. The product can be seen as a bridge, road, building, mine shaft etc.
- The SC is temporary in nature, only producing once-off, engineer-to-order projects through continual reconfiguration of project organizations and separates the design and construction aspects of the project.
- The SC is a typical make-to-order supply chain; every project creates a new product or prototype and often ventures into the engineer-to-order realm.

Construction can thus be defined as the design and assembly of various components and products in a fixed location, by either a single contractor or a collection of various contractors, in an effort to produce a semi-standard product or a completely unique, one-of-a-kind product, often by employing specialised and innovative techniques and processes.

Vrijhoef and *Koskela* went one step further by defining not only the abovementioned characteristics of a construction SC but they also defined the four main roles of SCM in construction as illustrated in Figure 2-12.

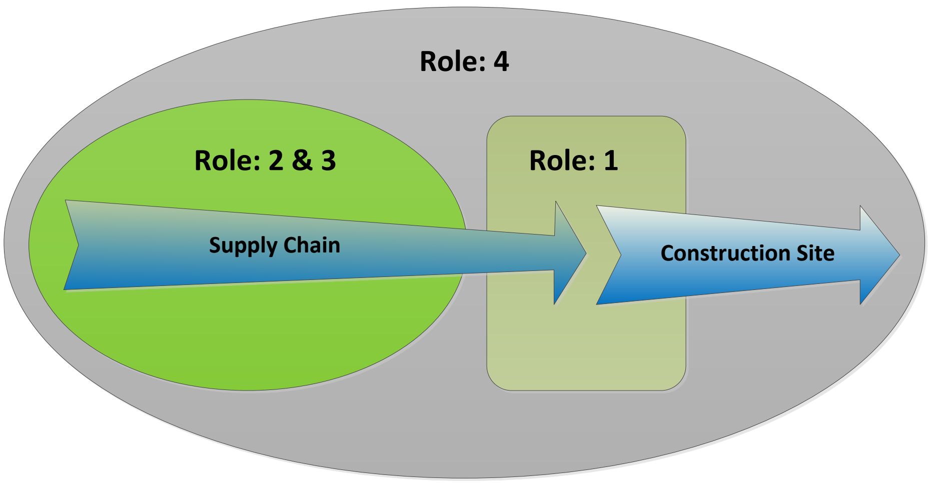


Figure 2-12: The four main roles of SCM in the construction industry

The management of the SC is to a large degree governed by the abovementioned characteristics. The roles of SCM in the construction context, as outlined in Figure 2-12 is as follows: Role 1 is a concerted effort by management to concentrate on the interface between the construction site and the supply chain, focusing on the impacts that the SC may have on the on-site-activities. Role 1 will generally be spearheaded by the on-site, primary contractor, due to their familiarity with site activities and their relationships with direct suppliers. Holistically the aim is to reduce the cost and duration of on-site activities. The type of activities that will come under scrutiny during the execution of this role will be material procurement and logistics as well as material and labour flows (Vrijhoef & Koskela, 2000). The focus will be on maintaining a dependable and sustainable supply of materials and skills from direct suppliers, in an effort to ensure that any work disruption is by no way due to inefficiencies in material and labour flows.

Role 2 is a specific focus on the supply chain, where a concerted effort will be made to reduce lead-times, inventory and logistic costs, ultimately reducing final project cost. Role 3 is once again a cost reduction practice but it focuses on transferring activities that would traditionally be classified as on-site activities and moving them upstream in the SC. An example of such an activity in construction is the use of prefabrication; components are designed and fabricated off-site at an earlier stage in the SC, streamlining the material flow within the site. This avoids sub-standard quality work that has become synonymous with in-situ construction and promotes concurrency and transparency between activities, leading to lower lead times and overall costs. This role is, more often than not, initiated by either the supplier or contractor. Role 4 is a high-level, strategic role that is dedicated to the adoption of integrated management, executed by management or even the client (Stewart, 1997). This role strives to improve the overall SC as well as site production and since the abovementioned roles are not mutually exclusive, this role of integrated management serves to coordinate and combine the different roles.

The outcome of this section's discussion is that potential does exist for the construction industry to consider a typical construction process as being a certain type of manufacturing, based on similarities between the two. The entire process of the construction may not be similar to a manufacturing application but, in most cases certain similarities will exist that in turn possess the potential for improvement and optimisation. In summation, construction cannot be classified as a single type of manufacturing. Rather, there should be specific stages or phases in each specific project that can be treated as a type of manufacturing. These identified stages or activities will then be isolated and managed in a specific manner, such as by implementation of manufacturing principles and ideologies. The different roles of SCM in the construction industry and their effects on the management of a certain activity also need to be considered when selecting an appropriate manufacturing technique or methodology to implement in the supply chain. The management of strategic activities needs to be conducted in such a way that there is specific focus on the supply chain and the adoption of SCM methodologies and techniques. The following section will investigate a few of the successful implementations of SCM, specifically manufacturing methodologies in the construction industry in recent years.

Construction processes derived from manufacturing

Production, in the form of construction can be seen as a process of value generation, transforming materials and ideas of little value into a valuable product when adopting a flow-view of production. In the case of construction this is usually a functional system or structure, the construction management of which is based on the control of the total flow of production. SCM plays a pivotal role in determining the degree of value generation that is achieved during the construction process. Modularisation and normalization of semi-manufactured items have always been ideals embraced in traditional manufacturing in order to increase efficiency, lower the cost of production, decrease delivery times, and increase the flexibility and variety of products that can be produced in an effort to meet and exceed customers' expectations (Segerstedt & Olofsson, 2010).

Olofsson also touches on efforts of previous attempts to introduce a strategic inventory buffer that will be used to briefly hold common sub-assemblies, only allowing for the completion of the final assembly once the precise customer requirements are known. By implementing this kind of buffer into a supply chain, one is able to postpone the point at which a product transformed from a stock-standard product to a once-off, customized product, such as those regularly encountered in the construction industry. This is known as a postponement strategy and it is extremely effective in moving the customer order point up-stream and has been extensively implemented with great success in the mass-customization industry, where this method proved to be effective in separating "base" and "surge" demands, similar to those encountered in the construction industry (Segerstedt & Olofsson, 2010).

However, an opinion that author *Winch* expressed is that "from an institutional view, the primary contractor and chief designer share the role of the system integrator", resulting in an unusual relationship between the production and the design phases of the "product" within the construction industry. The result of the abovementioned relationship is that the customer of a construction company (first tier customer) is very often isolated and as a result becomes an agent where the first tier customer delivers to second and third tier customers. The result of such isolation is that the final, real customer, is not known during the planning and execution phases, making planning difficult (Winch, 2003). The fact that the construction process is frequently 100% complete by the time the final customer is identified means that a lack of transparency exists between the construction team and the design team, resulting in poor short-term planning, longer construction periods, amplified delays and larger demand for material buffering measures, ultimately leading to a project that is over budget (Čuš-Babič, Rebolj, Nekrep-Perc & Podbreznik, 2014).

A developer may, for example, decide to construct an office block with certain characteristics for a certain market segment clientele, this is then the structure that is constructed. The developer then leases out the structure to a second or third tier customer that has very different and often specific needs and requirements that have not been taken into consideration by the developer. This results in retrofits and rework in order to satisfy the previously undefined second or third tier customer requirements, the very requirements that should have been considered from the start of the project.

Comparison with make-to-order supply chains in manufacturing

Typical problems that tend to arise in make-to-order supply chains were identified and quantified by *Koskela* (Vrijhoef & Koskela, 2000). By assessing various analyses conducted in different companies that produce non-standard products from numerous manufacturing industry players, similar trends were found, highlighting specific recurring problems in a make-to-order-type SC. The problems were found to propagate and amplify along the supply chain and are generally found to exist at each interface of the production process.

Customers are traditionally seen as the primary source of changes to the specifications of a make-to-order production cycle, leading to major rework and budget overruns. This was however disproved by the research conducted by *Koskela,* who argued that most control problems as well as changes to product specifications are of internal origin and not as a consequence of customer requirements. *Koskela* argues that the root cause for changes to the specifications of a make-to-order production cycle stem from the interaction of the various units of the SC.

The role front-line units, those that are held responsible for sales and often for coordination of execution and installations are vital in determining the level of performance of the whole supply chain (Wang et al., 2010). *Koskela* concluded that make-to-order logistics networks should be a focus area for development due to the overwhelming potential that can be exploited by using SCM methodologies, instead of managing individual delivery units, rather manage the overall delivery processes. These results concur with those obtained in previous research and compare to typical problems in make-to-order SC's within the manufacturing industry (Vrijhoef & Koskela, 2000).

Manufacturing principles and their application in the construction industry

The so-called Last Planner System (LPS) was proposed by *Ballard* as a solution to the so-called *Role 1*, the interface between the SC and site activities (Ballard & Howell, 1998).

LPS is a more collaborative structure to that found in conventional Project Management (PM), it is a social structure that enables the implementation of pull control instead of traditional dictator-like push control. In a traditional push control system, start dates, durations and commitments are strictly managed and controlled, while each task is meticulously monitored. In a pull controlled system information is pulled rather than pushing the control, built on the fact that the last planner, the person responsible for an activity, decides at the last responsible moment how the task is going to be carried out and how the overall targets are to be achieved.

This is a very good and structured approach to pull planning, capturing of contractor commitments and also the planning on the controls on the construction site, including the executable day-to-day tasks (Forbes, 2004).

More reliable promising mechanisms allow for a controlled release of work and by adopting and refining promising methods, schedule adherence could be significantly improved. The LPS involves the necessary parties in the planning phase, ensuring that contractors are not simply adhering to a plan that they have been given, but rather collaborating with a plan that they have helped develop. By effective communication and information flow collaboration, contractors are kept informed and have access to information that will improve their forecasts, estimates and planned schedules. This approach improves the degree to which a contractor will adhere to a plan or commitment (promise) to complete work and ultimately allows for better material and information flow within on-site activities.

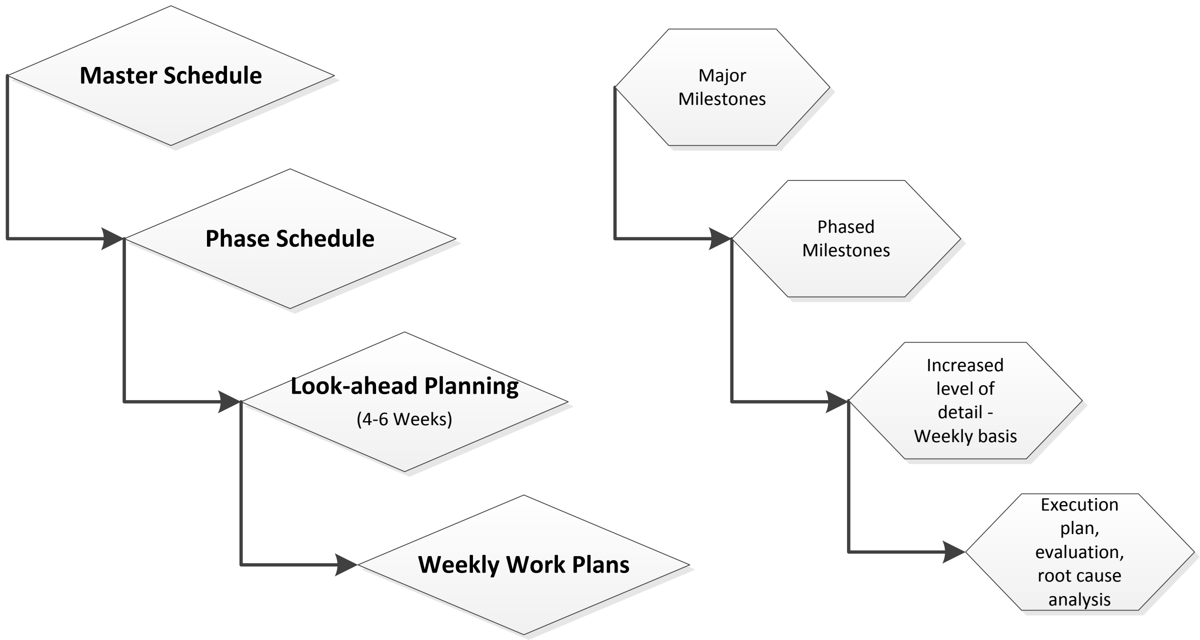


Figure 2-13: Scheduling as per the LPS method

A more reliable plan paves the way for improved schedule adherence and realistic project end-dates, a benefit for any manager and a desired outcome for any project. Scheduling as per LPS is as outlined in Figure 2-13, where a master schedule outlines only the major milestones, phased scheduled phases, more specific milestones and look ahead planning schedules on an even more detailed weekly work package basis. Weekly work packages are further broken down into a set of executable tasks and plans that are easily measured and controlled from a management point of view. This structure allows for effective management, even in projects where project managers have had no formal project management training, much like many of the projects in developing countries, South Africa being one of them (Letseka, 2014).

A possible method used to monitor the release of work is to implement a Tasks-Made-Ready (TMR) approach where constraints are removed prior to execution of a task. In the TMR environment, a task will be made "ready" by ensuring that all of the prerequisites associated with the task are complete, essentially ensuring that the task can be started immediately, without any delay.

TMR involves implementing a workable backlog, planned percent complete matrix and root cause analysis, none of which will be discussed in this paper. These principles are directly derived from industrial applications, such as manufacturing.

Authors such as *Ballard* and *Howell* suggest that in the not-too-distant future, manufacturing will in fact become more like construction, implying that principles implemented in construction will lead the way for industrial development in manufacturing and production, transforming the construction industry from what is currently viewed as an antiquated industry into a leading, trail blazing and cutting edge industry (Ballard & Howell, 1998). *Ballard* and *Howell* pose the question, "what type of production is construction?" To answer this one needs to delve into the very essence of what construction encompasses. Is a construction project sluggish, definite, or simple or can it be dynamic, fast, uncertain or intricate? If one was to view a particular project as being sluggish and simple, a manufacturing strategy could be viewed as the most appropriate strategy to implement in the particular project. By adapting the construction process to be more like manufacturing, through processes such as standardization will allow one to more easily implement strategic manufacturing-type approaches to the construction process. This will enable the construction process to benefit from the advantages of manufacturing ideology and feed off the comprehensive body of knowledge relating to manufacturing, theoretically optimising and transforming the construction process. This has the potential to completely transform the way in which that SC is organised and viewed within the construction industry, from a dull, static process to a new dynamic, strategic process.

On the other side of the coin is a project that is dynamic, always changing and plagued with uncertainty, in such a project the adoption of just a manufacturing strategy will prove to be insufficient (Ballard & Howell, 1998). The unique and dynamic, one-of-a-kind type projects that are frequently encountered in construction are riddled with uncertainty and complexity, making the management of production of a unique product complicated from both an organisational and operational point of view. For this project configuration it is imperative that a multifaceted approach is used instead of a singular manufacturing approach, when attempting to apply manufacturing ideals and principles to the management of said such projects and their supply chains. Because of the prevalence of these so-called "dynamic projects" *Ballard* and *Howell* suggest that construction is in fact an intrinsically different type of production to that traditionally encountered in the manufacturing industry, due to the fact that there will always exist a component of the process that is completely different to anything currently encountered in manufacturing. *Ballard* and *Howell* advocate that the development of a strategy able to directly apply lean principles to construction may require development of lean thinking beyond the point at which it is currently at (Ballard & Howell, 1998). There may exist scope for this in the future, but at the moment this remains out of the realm of possibilities. As the manufacturing industry strives to become a "customization" industry by means of instantaneous production and rapid product development of custom products, product uniqueness naturally has become a more common characteristic of manufacturing (Forbes, 2004), reinforcing the belief that lean construction principles will in fact drive development in the manufacturing industry in the future and not vice-versa as is currently the industry trend (Nudurupati, Arshad & Turner, 2007).

Construction industry contracting models and their relation to manufacturing

Most, if not all construction activities that take place within the borders of the Republic of South Africa are governed by two main bodies of knowledge when it comes to the point of view of contracts. These are the Joint Building Contracts Committee (JBCC) and the General Conditions of Contract (GCC) respectively. The JBCC is a committee that is representative of developers, building owners, professional consultants and contractors who, in a collaborative manner, shared their experience and intellectual property in order to draft the JBCC documentation framework. All said such documentation is published for the sake of transparency, standardisation and good practice.

First formalised in 1997, the JBCC aims to compile current, up-to-date contractual data that has an equitable distribution of contractual risk in the building industry. The committee is certified by the South African Construction Industry Development Board (CIDB) and is implemented throughout national and provincial government divisions. The GCC is concerned with construction works and is essentially a collection of 58 clauses that establish the general risks, liabilities and obligations of contracting parties involved in a construction project and the administrative procedures for the administration of the said such contract (CIDB, 2008).

The GCC model facilitates monthly payment to Contractors based on an estimate of the value of the work that have been completed at a certain point in time, a percentage of the materials on site, any additional payments that are due and any price escalation that may be stated in the contract. Claims by contractors and variations to the contract are handled using the framework in Figure 2-14.

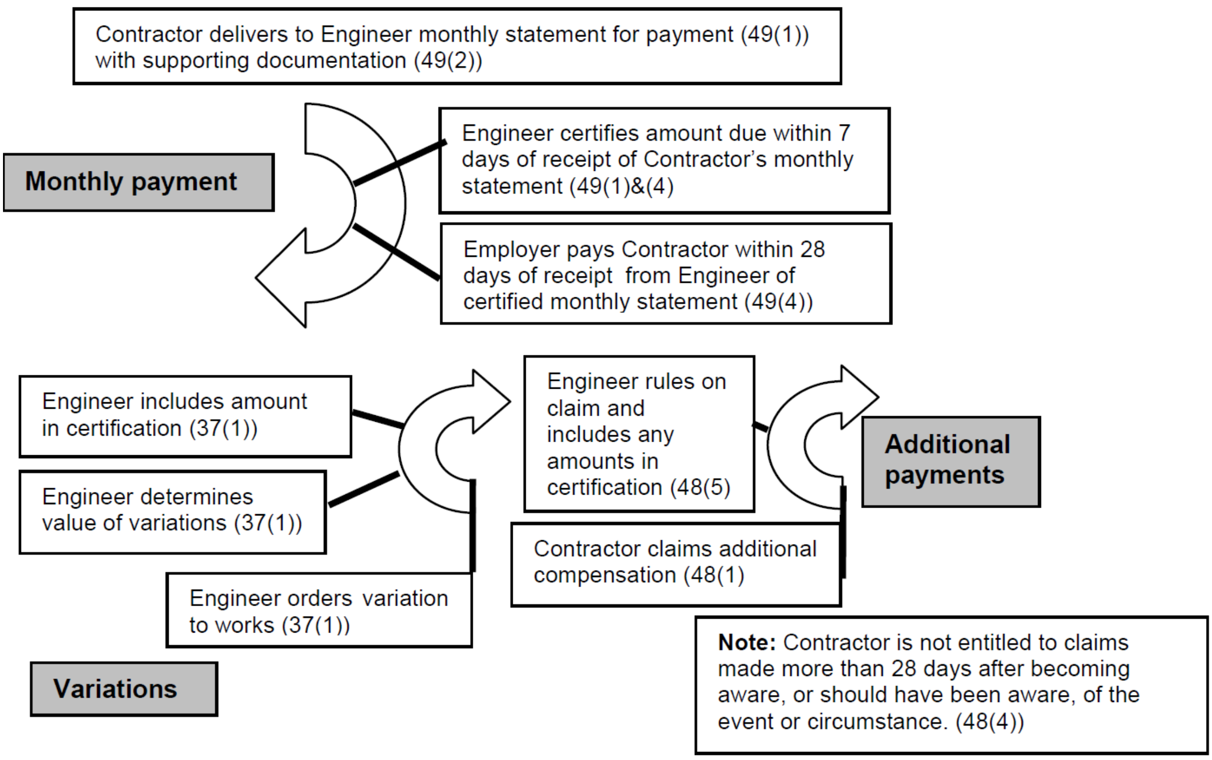


Figure 2-14: Claims and variations as per the GCC contracting model (CIDB, 2008)

The GCC ensures that clients are familiar with the rights and obligations of all parties involved in doing business with government (The National Treasury, 2010). These conditions are legally binding and serve as a set of guidelines for any government authorised procurement or project execution. Figure 2-15 outlines the framework that is the GCC in relation to the typical project phases of a construction project. All references to clauses in Figure 2-15 are direct references to official GCC legal documentation.

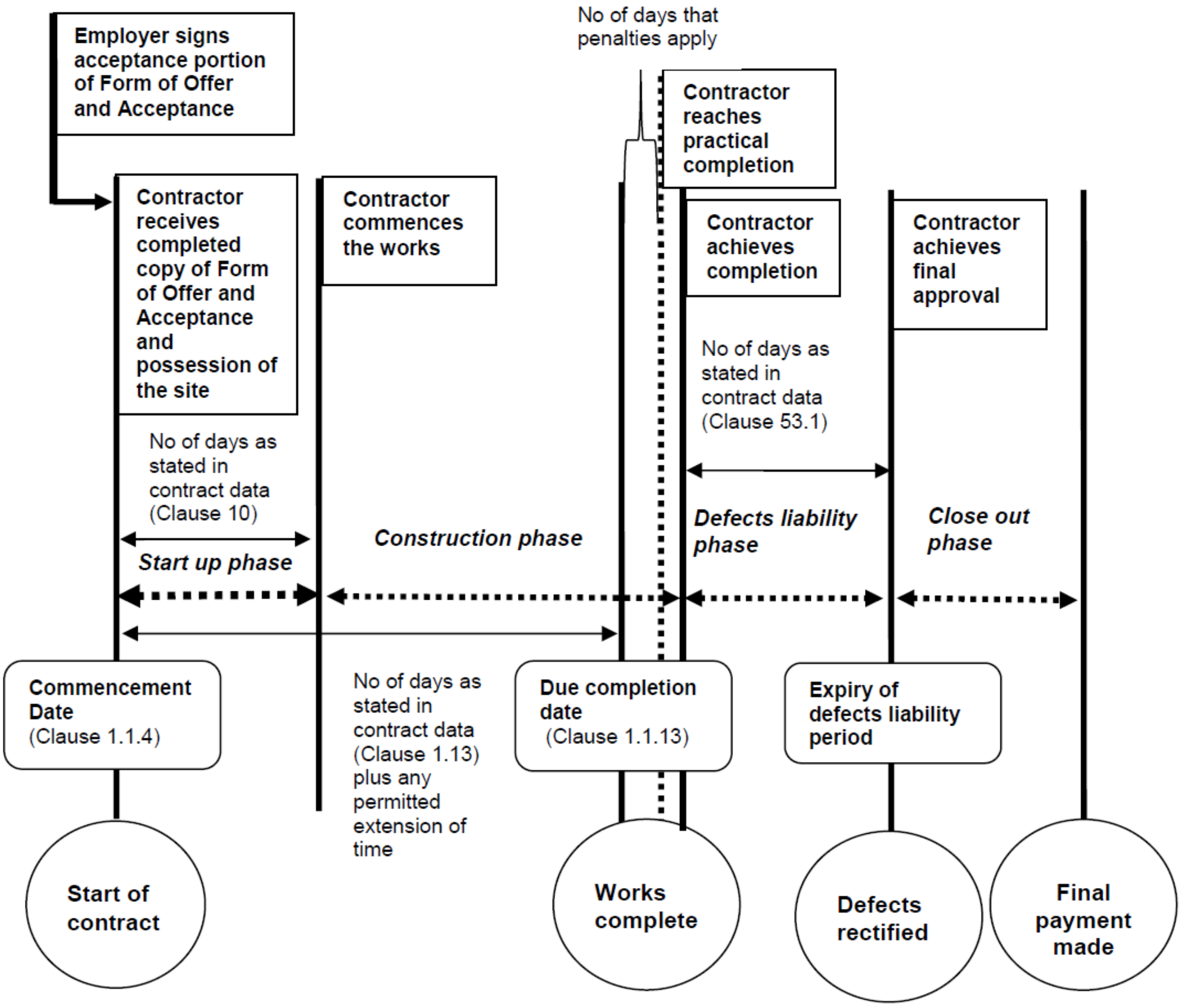


Figure 2-15: The GCC operation framework (CIDB, 2008)

Contracting models and their relation to manufacturing principles

The traditional contracting model implemented by most of the large construction companies in South Africa, including *Murray and Roberts*, *Group 5* and *Stefanutti and Stocks* is the Design-Bid-Build model (DBB). The DBB contract is a model of construction management, in which the general contractor is appointed through a tender process after designs have been completed and approved by the architect and engineer. The contractor will then "bid" or tender to do the prescribed work as detailed in the aforementioned designs, provided by the engineer and/or architect. This model is used extensively across the world, particularly for building and process plant projects. The contractual documentation that accompanies the DBB model includes a formal agreement, conditions of contract, employers requirements and expectations, contractors proposals, schedules and rates (Longley, 2009).

The advantage of such a contracting model is that the employer only has a single point of responsibility and thus maintains a greater cost certainty over the duration of the contract. This model reduces conflict between contractor and designer, increases constructability (Longley, 2009), allows for value engineering and presents an opportunity for the contractor to increase profit by means of schedule fast tracking and schedule adherence.

A *cost plus contract* can be successfully implemented in this model by means of effective cost and value engineering, milestone reimbursements and a pain and gain sharing arrangement. In a pain and gain sharing arrangement, both the contractor and the client agree that in the case of a budget overrun or saving, each party will share the loss or gain in agreed upon proportions. This is often a great incentive for contractors to work effectively but requires extremely close supervision from the client and consulting engineer in order to ensure the contractor is not producing work or providing a service that is of an inferior standard.

A DBB contracting model is similar to mass production in manufacturing, proving to be extremely wasteful in many areas with sub-optimisation prevailing within certain stand-alone business units, the consequence being that global improvement is virtually impossible. However there exists an adequate contracting model known as a Design Build contract. A Design Build type contracting model is most favourable when trying to incorporate manufacturing principles into the construction environment. This model has the most potential to be successfully implemented in construction product development (Ballard & Howell, 1998). The implementation of a design build contracting model is a risk aversion ploy on the part of the owner, who shift risk from themselves onto the contractor and design team, similar the manufacturing environment where factories are contracted to design and manufacture a certain product.

EPC is an acronym for Engineering, Procurement, and Construction. This is a type of contracting agreement that is used predominantly in the construction industry as well as in the mining sector. A main contractor will serve as the engineering and construction contractor and will complete a detailed engineering design of the project as well as oversee all the procurement of both equipment and materials that are deemed necessary for the successful execution of the project. The same contractor will then construct the facility to deliver a functional asset to the client. These companies are known as EPC Contractors.

As with most construction related contracting models, an EPC Contractor will be expected to execute and deliver the specific project at a previously agreed-upon date and for a specific price. Such models employ a Lump Sum Turn Key (LSTK) Contract due to the fact that an EPC LSTK Contract positions both schedule risk and budget risk on the EPC Contractor rather than on the client as discussed earlier. The client will generally manage the EPC Contractor via a management team that more often than not refer to specialised Project Management Consultants to ensure that the agreed upon work is being executed in accordance with the contractual agreement (EPC Engineer, 2015).

EPCM in the construction industry refers to Engineering, Procurement, and Construction Management. This type of contract is different to a contract where the contractor is directly involved in construction like is the case with an EPC Contract. An EPCM Contractor has clearly defined responsibilities in the overseeing of the actual Construction Contracts. An example of EPCM Contractors are *Hatch* and *Fluor*.

Since a production site consists of well-coordinated, well-planned activities, such activities can be adjusted and translated to cost that will ultimately result in a contract that supports and promotes a supply chains approach to management (O'Brien, 1998). The selection of a contract structure/type can prove important when it comes to effective management of a project.

2.4.3 A Lean Construction Supply Chain

As discussed earlier, developing nations such as South Africa host a construction industry that is traditionally one of, if not the biggest industry in the country, essential to economic and social development of those nations. According to a study conducted by *Forbes*, the majority of construction is conducted using outdated techniques and suffer from severe SC deficiencies. Rework and scope changes are also cited to be a cause for major concern in the industry as research indicates that up to 30% of construction cost is due to poor quality work and an unacceptable level of inefficiencies, mistakes and schedule delays as a result of poor planning and poor communication (Forbes, 2004). There exists no concrete answer as to why the construction industry is so far behind other industries when it comes to quality and performance, most of which have significantly increased both their levels of performance and the quality of their products. As global players become more prevalent in developing countries, such as South Africa, local industry will have no other choice than to improve their levels of performance and quality of their product in order to remain competitive. Chinese and Russian companies have started to slowly but surely penetrate markets that are available in developing economies such as Mozambique, indicating the necessity for local construction industry to assess their performance and explore possible solutions the problems they face. The range of reactions to Chinese involvement across Africa has varied from enthusiastic embrace by elites to caution from businesses, trade unions and civil society and even hostility from some local communities but one thing is certain, the Chinese provide a well-priced service and produce a high quality product at a low cost, a clear warning sign to local contractors and construction industry players to adopt measures that will enable them to remain competitive in a market that is fast becoming saturated with such international competition (Alden, 2014).

It seems that many companies in the construction industry have recognised the need to improve and adapt in order to remain competitive in the industry, according to *Aouad* and *Cooper* who have considered the implementation of new procurement systems as well as manufacturing and production strategies and philosophies that can be adopted in a project-type environment such as construction (G. Aouad, R. Cooper, n.d.).

According to *Ballard and Howell*, the lean revolution is a theoretical revolution, at the heart of which is flow and value models. The flow model facilitates waste reduction, currently the main focus point for Lean thinking initiatives in construction while the value model facilitates value maximization within the company through collaboration and negotiations between client and customer. The implementation of such a lean production initiative will comprise of at the very least, two parts; the transformation from certain conventional techniques that share similarities with manufacturing to contemporary product manufacturing and in cases that are dissimilar to manufacturing as well as trying to limit the idiosyncrasies of construction in order to be able to take advantage of the implementation of lean techniques and ideals such as those that have become synonymous with manufacturing industry (Ballard & Howell, 1998).

2.4.4 Complementary Construction Elements

Modern day construction is no longer dominated by in-situ type construction as was the case in the past. The further development and refinement of prefabrication techniques has been fuelled by the need to significantly reduce the enormous quantities of waste generation that has become commonplace in the construction industry (Tam, Tam, Zeng & Ng, 2007). The drive towards the implementation of prefabrication alone unfortunately does not seem able to provide satisfactory reduction in waste in the construction industry. A multifaceted approach is necessary, involving the entire supply chain, if true waste reduction is to be realised and exploited to provide competitive advantage.

Complementary element construction (prefabrication) is essentially the process of constructing a structure out of several semi-finished elements, similar to assembling a puzzle. Elements are manufactured at an off-site location, under the authority of an off-site supplier and are then erected one-by-one on site as part of a single monolithic structure. This is analogous to purchasing *Lego* blocks and then constructing a larger structure out of the individual *Lego* pieces. In this type of construction much of the construction risk is transferred from the on-site contractor to the manufacturer of the complementary elements where as traditional in-situ construction methods place all the risk on a single contractor or group of contractors. This often is cause for major financial turmoil as the risk is exclusively on the "shoulders" of a single entity. Contractors compensate for the level of risk associated with a project by increasing the monetary value of their tender in order to offset the risk of the project, ultimately driving up the overall project cost. In the case of complementary element construction this effect will not be as prevalent since risk is shared by many contractors, most of which are specialists in their specific field, capable of delivering high quality goods and services in a timely manner (Chen, 2011).

Authors such as *Tam* and *Zeng* conducted studies that assessed, through feasibility analysis, the feasibility of adopting prefabrication in construction. They concluded that there is significant scope for the reduction of waste generation through the implementation of prefabrication, stating that there are currently still many problems with the application and implementation of prefabrication. The risk compensation effect discussed in previous sections was found not to be as dominant in prefabrication as in in-situ construction. Additionally, the need to successfully execute the design phase of a project that proposed the implementation of prefabrication along with the development of effective prefabrication models was outlined as key focus areas of future projects that are to follow a prefabrication method of construction (Tam et al., 2007). They found that waste generation can be reduced by as much as 100% by adopting complementary element construction, formally referred to as prefabrication. This waste reduction is realised through improved concrete casting methods and more efficient concrete formwork management as well as precision in planning that is possible in a controlled factory-like environment. Improved planning associated with prefabrication as well as the prevalence of skilled workers in such an environment significantly reduces the need for rework, thus significantly reducing waste and project cost.

Furthermore, prefabrication should reduce the environmental footprint of a project an ever present factor that requires careful consideration both now and in future. The above-mentioned benefits associated with the adoption of prefabrication has the potential to lead to significant reductions in cost and time, even though initial construction costs such as initialisation are inflated when implementing such construction methods. However, the benefits far outweigh the risks.

The cost of implementing prefabrication

In order to effectively supply a construction site, no matter the size of the project or complexity of the construction, effective production planning is paramount. Production planning aims to supply a site during a planned time frame with workers of the correct skill level, with the correct tools and equipment and with the correct materials in sufficient amount and at the correct locations. Workers, regardless of seniority should have clearly defined tasks and responsibilities in order to facilitate the completion of the agreed-upon work, such that it will be completed according to the agreed-upon date to the agreed-upon quality and at no more than the agreed-upon cost (Huemer, 2006). If the production planning process is not followed correctly there is a risk that cost-intensive improvisations, unproductive down-time, idle machinery and misleading production results will become prevalent, leading to accidents and potentially dangerous situations, ultimately delaying production and increasing the overall cost of the project.

In Table 2-11 basic principles of in-situ construction are compared with prefabrication for an arbitrary theoretical concrete structure (Chudley & Greeno, 2008).

Table 2-11: Theoretical Comparison between in-situ and prefabrication construction

	In-Situ Concrete Construction	Complementary element Construction
Crane Capacity	2.5 t	20 t
Progress Bottleneck	Formwork and reinforcing placement as well as concrete curing time	Crane cycle time
Production Quality	Good	Excellent
Labour requirements	100%	40%
Average labourer skill level	60%	100%
Level of mechanization	60%	100%

As is evident in Table 2-11, a complementary element construction method requires significantly more initial investment and capital outlay, due to the fact that the site is highly mechanized and the skill level of workers is high. Although initial capital outlay may be more than that of traditional in-situ construction methods, the quality of the finished product is considerably higher when prefabrication is used, as opposed to in-situ construction methods. This provides significant advantages for certain construction applications, such as when constructing repetitive and conventional shaped structures as well as when “standard” elements are required, such as elevator pits, retaining walls and lintel beams. Prefabrication leads to shorter construction periods and less site congestion, which translates into safer working conditions and improved product quality, as mentioned earlier.

The intricacies of designing for complementary element construction, of which there are many, will not be discussed in this study but should be considered when opting for prefabrication construction. The focus of this study is not on the particular details of complementary element construction, but rather on the holistic management of such a project.

2.4.5 South African Construction Economics

This section will act as a supplementary section to section 2.3.1 in order to provide the reader with a more in-depth look at the economics as well as political aspects of the South African construction industry.

The status of the construction industry in South Africa is one of two extremes. On the one hand, the industry is as active as it has ever been, coming off the back of the 2010 FIFA Soccer World Cup the industry has residual momentum the outlook is optimistic. On the other hand the outlook it more pessimistic after a fall to 55 points in the construction confidence index in the first quarter of 2014 from an optimistic outlook of 66 points at the end of 2013 (Mark, 2014). The so called “neutral point” for the index is at 50 points (Egan, 1998). This neutral point was reached in the third quarter of 2014, mainly due to increased unemployment and pressures on profitability (CIDB, 2014). The *StatsSA* quarterly labour force household survey indicated a significant employment loss in the construction sector of around 17 000 jobs in the second quarter of 2014, with the total construction employment of 1 182 000 jobs over the same period, roughly representative of 8% of the total in South Africa (StatsSA, 2014). The variation between the JSE All Share Index and the construction index over a period of time spanning 2008 through to year ending 2013 is illustrated in Figure 2-16.

According to an article published in the *SA Commercial Property News* website during the third quarter of 2014 there exists an indication that the JSE’s Construction and Materials Index shows a sector that is in trouble. The sector is described as struggling, the reason being attributed to slow economic growth as well as a slowdown in government spending under the multi-trillion rand infrastructure plan (SA Commercial Property News, 2014). The article explains that construction companies are in for a tough few years as earnings are expected to decline, as well as having to deal with cautious stock investors, with major players in the construction industry such a *Basil Read* having poor year-on-year headline earnings-per-share. The sector did however show positive development in the Asia-Pacific region, attributed to the demand for minerals prevailing from the insatiable Chinese economy that has resulted in major development of both gas and oil projects in this region.

As a result it is expected that many of the large construction industry players will attempt to diversify, specifically focusing on emerging African markets. In summary, the domestic construction market sector remains unstable with a cautious outlook (SA Commercial Property News, 2014).

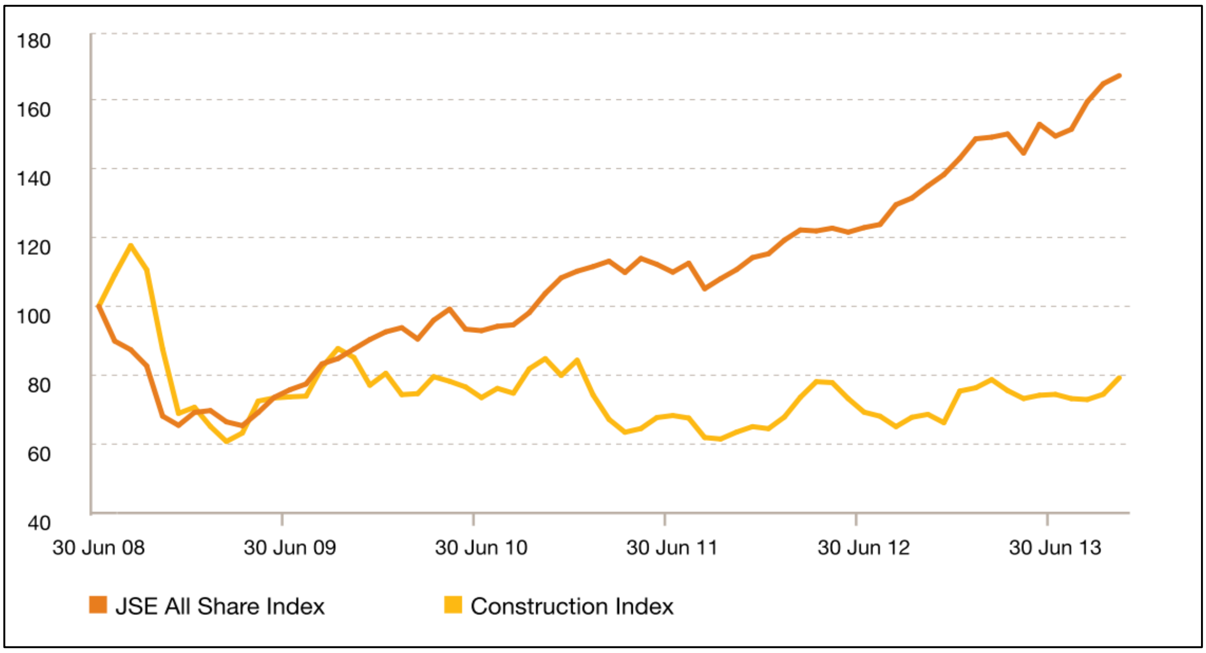


Figure 2-16: Johannesburg Stock Exchange & Construction Index comparison (PWC, 2013)

According to an article in the *Business Day Live*, in which the outlook of construction in South Africa was deliberated upon, the drop in the confidence index is due to a mild deterioration in profitability and a lower-than-expected predicted increase in construction activity across both private and public sectors, with the author suggesting a resilient recovery, as there was an expected increase in construction and profitability alike in the next two quarters of 2014. The article highlights the optimistic future outlook of the index, albeit in the midst of ongoing industrial action such as mining strikes and the closure of key manufacturing industry players such as steelmakers and aluminium smelters (Mark, 2014). These variations that have been discussed illustrate the fragility of the construction industry at present.

According to a Price Waterhouse Coopers (PWC) report on construction industry trends, the annual public sector expenditure on infrastructure is a relatively good indication as to the wellbeing of the industries' performance and with the passing of an innovative *Presidential Infrastructure Coordinating Commission* (PICC) as well as the continuation of the existing Infrastructure Development Plan there is expected to be a great deal of said such spending in the years to come. The PICC is tasked with the streamlining of expenditure between different government departments, effectively coordinating government's Infrastructure Development Plan and paving the way for positive future growth with the industry (PWC, 2013). Although the largest 10% of public sector capital projects are only tendered on by a small community of roughly ten large South African construction companies, the majority of these projects are subject to serious segmentation in the form of sub-contracting, facilitating the percolation of profit down to specialist firms, especially BEE firms (CIDB, 2014). Similar trends hold true for the distribution of private sector tenders.

According to a report completed by the CIDB, covering the period between the 4th quarter of 2013 and 2014 respectively, the total municipal capital expenditure and provincial budget amounted to R 47.9 billion and R 52.3 billion respectively, an underspend of roughly R 14 billion (CIDB, 2014).

Taking the above-mentioned into consideration, what is the status, the outlook, of the construction industry in the South African market context? Much like the findings of the famous British *Egan Report* of 1998, the major factors facing the construction industry are as listed below:

- Low profit margins on projects
- Limited continuity and innovation due to fragmentation in the form of sub-contracting
- Poor industry career structure
- Lack of training
- Ineffective BB-BEE initiatives (specific to the South African context)
- Poor contractor selection criteria (cost) adopted by client and consultant

The *Egan Report* was a study conducted on request of the deputy prime minister of Britain, *John Prescott* in an effort to find a way in which to improve the efficiency and quality of the construction industry in the UK. The conclusion of the enquiry was that, in order for the construction industry to improve its quality and efficiency, they would need to overcome fragmentation, improve communication and improve coordination (Egan, 1998). The underlying reasons behind the above-mentioned recommendations was that there was found to be an increasing degree of fragmentation of both the markets and industry, driven by an increase in specialised contractors and suppliers, as well as a migration of value-adding activities away from site production. Prefabrication and off-site preassembly is an example of this.

Traditional projects, such as those commonly found in South Africa, are executed by means of a design and a separate construct process, where the design process and construction activities are managed by separate professionals, often specialists. This construction model results in designers not being adequately informed as to construction capabilities, limitation and needs, such as safety and constructability, where a construction firm would “inherit” a design, without any prior input and would have to execute the prescribed design in a silo-management type environment. Designers and construction firms would work apart from one another, in silos, isolated from intercommunication and cooperation. This has resulted in costly construction, unsafe and uncoordinated designs as well as extended construction schedules that all ultimately are to the detriment of any project’s success. This is further exacerbated by globalisation and formation of international project teams. As was the recommendation of the *Egan Report,* the UK industry as well as the South African industry have subsequently, over the last decade, moved from a design and then build model of construction to a design-and-construct model. This model allows the design process to incorporate the inputs of both the contractors and designers of the particular project, with both design and construct processes being managed by a single contractor or dedicated group of contractors. Ideally the client will also be involved in this process in order to limit the amount of rework and scope change that might arise if the client was to deem the design unsatisfactory. It is thus important to involve the client, as the majority of the rework on site is brought on by the client's decisions.

Problems in design management and execution are caused by poor communication, inadequate documentation and lack of coordination between stakeholders, due to a lack of both planning and integration of design and construction, as well as insufficient information management (Sarker et al., 2012). These problems lead to both design and scope change, that ultimately delay project completion and lead to budget overruns (Leukel & Sugumaran, 2013). It is of paramount importance that these processes be measured and implemented successfully. This could potentially be managed and delegated by implementing a SCOR or more specifically a BSCOR model, into the construction process at an early stage, ideally in the pre-planning or planning phase of a project.

Each and every process and task related to construction activities need to consider how time is used. Time management is thus a key driver of performance in all construction processes with time being a KPI for of supply chain performance measurement. There are many approaches to SCM and supply chain performance that seek to improve production efficiency, by identifying areas where there is no value-add achieved and streamlining the associated processes in order to eliminate tasks where time is lost (Whicker, Bernon, Templar & Mena, 2009).

2.4.6 Project Time Management

Since delays in construction projects have been the source of various research efforts (Doloi et al., 2012; Li & Liu, 2013; Albert et al., 2004; Revilla & Sáenz, 2013; Thunberg & Persson, 2013c) over the past two decades, naturally time management is a topic of interest in in any research relating in any way whatsoever to project delays.

In short, project time management is the process of identifying specific activities that need to be completed in order to produce a specified deliverable, by analysis of activity durations and resource requirements in an attempt to effectively control changes to project schedule. Time scheduling is specific to each concerned organisation and the point of view and requirements of the client and contractor often differ considerably. Where the client is primarily concerned about fixed dates of tender and contractor obligations, payment schedules and project time frames, a contractor is mainly focused on managing time pertaining to operations. The detailing and scheduling of sub-processes, the selection of work procedures, cost scheduling and synchronization of resources are among the time management concerns specific to a contractor (Bargstadt, 2013).

Time scheduling methods are chosen by the project team, graphic methods that are commonly implemented in a South African context include, but are not limited to *network planning*, *Gant charts*, the *line method* and *time lists*. There is a further cutting-edge method of time management that is slowly creeping into the construction industry, reinforced by an industry-wide adoption of Building Information Model (BIM), the new time-management-technique is known as *screenshot scheduling*.

Each task is taken from the BIM model and is accompanied by a multimedia package such as a 3D model or video clip, that contains instructions and recommendations as to the required time of completion and required resources among others, all managed and coordinated using the BIM and its associated scheduling software package plug-in, a very important industry transformation as far as SCM is concerned (Watson, 2011). This is also perfectly suited to the South African industry, where skill levels and literacy rate are often extremely low.

Each one of these methods has their niche area of application, each enjoying varying degrees of success, depending on the specific situation and project-specific constraints. Each of the abovementioned methods also require a certain degree of process detail in order to be implemented effectively. This discussion falls outside of the scope of this study but is mentioned for the sake of completeness.

2.4.7 The Theory of Constraints and the Critical Chain

The theory of constraints, commonly referred to as TOC, is a set of logical procedures based on structured common sense. TOC is a management philosophy that implements an effective set of research methods that are adequate for the management of both processes and people. TOC is well-known for its broad set of robust applications in various diverse industries. Arguably, the biggest challenges facing managers are: gaining a competitive advantage over competitors, improving employees' productivity whilst maintaining throughput and being able to manage client expectation, whilst adhering to schedules and budgets (Goldratt, 1997). In the TOC world, both the individual processes and the links between them, their inter-relationships, are of importance when attempting to improve the overall performance of a global process. The TOC principle is a simple one, comprising of five clearly defined steps as illustrated in Figure 2-17. TOC is not a blue-sky-thinking idea, it is practical framework that is firmly grounded in reality. TOC considers a number of data-points, tools and processes that are related to the concept of constraints that in turn translates into a useful body of knowledge that can be effectively applied in practice. Thus, TOC is not just a theory but rather a sound application of theory, it is a solution used to manage constraints of a system.

The steps illustrated in Figure 2-17 need to be executed, starting with the identification of system constraints that exist in a specific process or chain of events. This step requires the evaluation of the entire chain (not only the current critical path) of a specific process, evaluating on a numerical and logical basis, the performance of each activity and identifying each constraint in the said process. The list of constraints then needs to be analysed in order to reduce the number of constraints to one or at the very most, two constraints, the most critical constraint of the process in question.

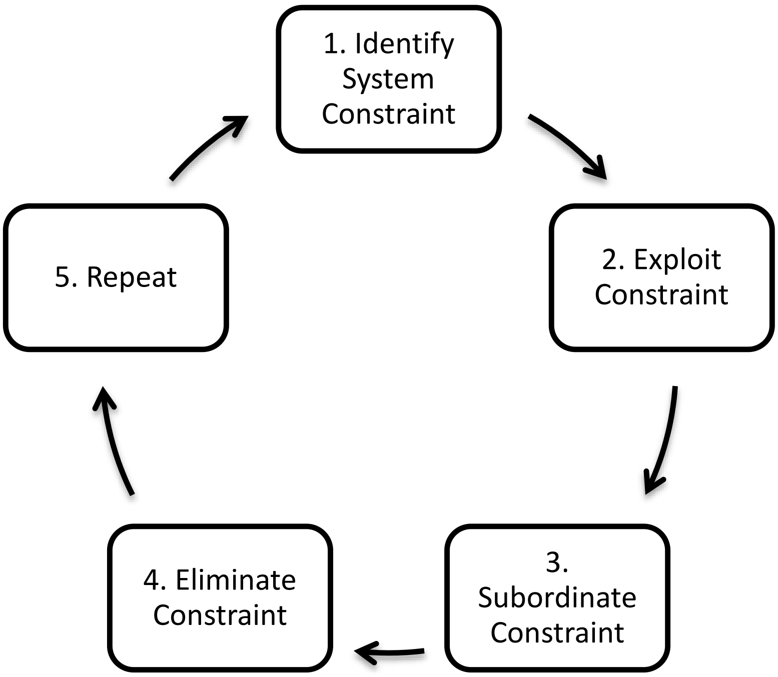


Figure 2-17: TOC implementation steps (Goldratt, 1997)

Once the constraint has been identified, the supply chain specialist or project manager must decide how to exploit the identified constraint, generally by either adding additional capacity to the constraint or by running the constraint at maximum capacity, this is known as “squeezing” the constraint. These are essentially the only two measures one can implement in order to improve the performance of a constraint, be it a mechanical or human resource. There are four main types of constraints; resource constraints such as machines or materials, the market/economic constraints, policy constraints and dummy constraints. Constraints that can be resolved in a short period of time and with a limited financial investment.

Once a constraint has been identified, known as the bottleneck, exploited and improved, the rest of the activities involved with the identified process need to be subordinated to the bottleneck constraint. This means that the rest of the organisation needs to be restructured around the identified constraint. Every process will contain at least one constraint. Examples of subordination will be to reduce over-production or reduce work-in-progress in order to smooth the demand on certain resources. The identified, exploited and subordinated constraint is then eliminated in the final step of the implementation process. An example of successful exploitation of a constraint would be once an investment has been made to successfully improve the constraint so that it is no longer the bottleneck in the process. For example, if a machine is the bottleneck, purchasing a new improved machine might be the solution to resolving the constraint. This process may be repeated once again to identify the new constraint of the improved process; this is an iterative manner of continuous improvement.

Critical Chain and how it effects management of projects

A critical chain, when considering a project schedule, is the longest resource and priority-feasible sequence of tasks that dictate overall project duration. The critical chain (CC) method is primarily implemented in scheduling of projects, as well as to monitor and adjust in-situ projects’ schedules (Zheng, Guo, Zhu & Zhang, 2014). The critical chain concept was born out of the need to improve schedules, budgets and resource allocation of projects with specific focus on so-called bottleneck activities. The bottleneck is defined in management theory as a process or activity that causes a global process to be delayed or stopped. So for instance, an activity in a series of activities that delays the following activities from happening is the bottleneck. This phenomenon is commonly encountered in traditional theory of constraints (TOC), a soft, almost philosophical approach to management while Critical Chain Project Management (CCPM) is a methodology for planning, performing and managing projects in either multi-project environments or single project environments, both of which are encountered in the construction industry. CCPM was developed and made famous by *Dr Eli Goldratt* who first introduced the concept to industry in 1997 (Goldratt, 1997). Implementation of a critical chain management methodology has the potential to increase the speed, predictability and productivity of projects whilst reducing errors, stress and time wastage. There are two underlying reasons that account for this improvement potential, deadline management and multitasking.

Deadline management is where individual milestones are managed according to various time deadlines, there exist a clear set of allocated dates by which certain tasks must be completed by.

There is a fundamental problem with the individual management of tasks by means of deadlines. Humans are inherently cautious and risk averse, the result being that since a person is ultimately held accountable for a commitment to a deadline, when a manager or engineer makes such time-based commitments, they inherently factor in safety into their estimates to account for the variability in the time it takes to perform tasks, a time buffer. For example, if a task is realistically going to take two weeks to complete, a vendor will communicate a five week completion time to the client, in order to ensure he fulfils his commitments. This extra 3 weeks is known as safety time or time buffer.

Project managers, on the other hand, require tasks to be completed by a certain date (usually an earlier date) and thus apply pressure to vendors and contractors to perform these tasks in a condensed time frame, often leading to negotiations and trade-offs on time, cost and sometimes even quality. For example, the project manager will allocate four weeks to complete the task after a lengthy negotiation process. The vendor could possibly complete the task in two weeks if he really had to, however the vendor will generally stick to his original commitment of five weeks in order to maintain bargaining power in future negotiations, as agreeing to a condensed time-line would compromise the vendor's ability to justify future tender timelines, thus losing his estimation credibility. Contractors very rarely will complete a task ahead of schedule, unless incentivised to do so. This is in order to provide credibility to their time estimates and to remain as risk averse in their operation as possible. Another factor that one needs to consider is the phenomenon known as the student syndrome. The student syndrome is when four weeks is allocated to complete a certain task that should take one week. The result is that the individual responsible for completion of the task will put-off (delay) the task until there is one week to complete the task, at which point they will work frantically to complete the task that they originally had four weeks to complete but now have only a single week to complete. This is human nature and has become a common and widely accepted practice in industry.

The outcome of this process is that a task that could potentially be completed in two weeks is now allocated four weeks to be competed in, hence the task becomes a four weeks task having essentially two weeks safety buffer. Once each and every task's overestimation has been considered, the final project time is extremely inflated. This leads to multitasking on the part of the contractor, who recognises the opportunity to complete other work in the two weeks safety time he has on the above-mentioned task. This is the second fundamental problem with regards to traditional project management. Multitasking, especially in a project environment, leads to poor quality work, a lack of continuity and switching between tasks (set-up time) leading to a loss of time and productivity. If this occurs in each and every task in the project schedule, it is evident that there is significant time wastage. Software packages can be utilised in order to schedule projects that suffer from resource limitations, which are virtually all projects in the context of construction.

Full Kitting

As discussed, TOC and *Critical Chain Project Management* centres around the reduction of construction lead time by reducing workload of the process constraint. In construction, the on-site project team is usually identified as the process constraint in an assemble-to-order construction environment, such as used in construction and more so in complementary element construction. TOC identifies a single system constraint, referred to as the bottleneck, a task that is the “bottleneck” of the construction process. If a process is a balanced line, a constraint needs to be created and clearly defined.

Working off the assumption that the estimated time-to-complete of each task is based on an optimistic estimate, a global time buffer is implemented to manage the overall completion of the project. Daily monitoring of task progress as a function of time is implemented in order to monitor buffer consumption as well as prioritise and synchronise tasks in a project. Once a constraint is identified, a buffer is be implemented to ensure the constraint is never starved of work. Buffer consumption monitoring is achieved by means of dynamic buffer management software such as *Symphony.*

Make-to-order items such as prefabricated slabs are managed by means of time buffers (since production lead-time of such items is the main concern) while make-to-stock items are monitored by means of stock buffers (since stock on hand is the concern, not production lead-time).

Full Kitting or *full-kit-assembly* could be successfully implemented for make-to-order items in the construction industry, of which there are potentially many items that are traditionally seen as engineer-to-order or make-to-order that can in fact be standardised. Standardisation of such items has been attempted in prefabrication, however, the scope for standardisation is far beyond what is currently being implemented in industry. The *full-kit-assembly* management approach ensures that all the prerequisites for a task are on hand prior to execution of such a task, only executing a task once all the prerequisite “kit” is available. This approach is fundamentally different to conventional construction where multiple tasks are executed in parallel as parts of the “kit” arrives. As a result, the on-site work in progress (WIP) is significant, resulting in multitasking by resources as each resource is reallocated frantically between tasks depending on the availability of “kit”.

Instead, TOC suggests ensuring that all the required “kit” is available prior to task execution, will resulting in more efficient resource utilisation, improved team morale and less waiting-time. This is achieved through prioritisation and synchronisation based on buffer consumption calculations. Reduction of waiting time and que time is a huge issue in the construction industry and forms the basis of the TOC principle. In the TOC world, “time-is-money” and “a chain is only as strong as its weakest link” where the weakest link is referred to as the critical process. We measure the flow of information, the flow of resources and the flow of money.

Thus, only the “critical process” or “bottleneck” is measured based on the premise that the bottleneck controls the progress of the entire project and as long as the bottleneck is not starved of work, an accurate estimation as to the project completion time is possible and effective management of such processes is possible. Such an approach could significantly improve the schedule and budget adherence of a construction project.

The solution to this problem is focused around speed and reliability of the supply chain. Task prioritisation can be achieved by understanding which tasks are critical and by how much, each task can then be prioritised using a software that has prioritisation functionality, this will limit multitasking in projects. Again, the traditional deadline management that is the culture in most companies needs to be aligned with modern management techniques, where tasks can be late or early, people are expected to work on individual tasks (no multitasking) and where progress is not driven by deadlines but rather by an overarching project time buffer that protects the deadline of the project as a whole, and not each individual task.

Creating global urgency and setting clear priorities within a project requires the cooperation of the entire project team. This often leads to problems, since human beings generally act autonomously and with their own conviction.

The effect of human nature on effective critical chain management

As is the case with most improvement efforts in many companies in very different fields of application, the human factor is the one that is the most difficult to manage. The same is true for the project environment found in the construction industry. The underlying problem is that human beings are autonomous thinkers with their own ideologies and affinities. Collaboration, as discussed in earlier sections, is a core principle of effective SCM and TOC implementations, however, collaboration is not a culture in modern day management. Employers need managers and employees with effective personal communication skills who can successfully manage people, however there are some human factors that cannot be changed through management. This can be described as human nature.

In the construction project environment and especially within task scheduling human factors exist that limit the effectiveness of any attempt to improve productivity or schedule adherence, for example, when considering the human nature of contractors that tender on tasks involved with a project. As discussed above, TOC claims that there should be no individual task time buffer (safety time) but rather there should be a global time buffer that can be accessed by each task if needed. In order to successfully implement this methodology, one requires a time estimate on tasks that includes absolutely no time buffer whatsoever, the shortest possible time-to-complete. Through years, decades even, of estimating, contractors have grown accustomed to estimating in a certain manner, usually over estimating the time required to complete a task, by adding safety to their estimates in order to comfortably fulfil their contractual commitment. Human beings are inherently cautious. It is not uncommon to find a task that should take five weeks, being tendered for as a seven week task where in actual fact the task can be completed in four weeks if “push-really-came-to-shove”.

Assume the CEO of a company asked his managers for a time estimate to complete a certain task. Assume the managers, after thorough calculations found that the task could be completed in four weeks. The managers then, in an effort to protect themselves from possibly exceeding the allocated time of 4 weeks, decide to add a week safety to ensure they deliver to their promised date and avoid any disciplinary action that might arise due to late completion of their task. The estimation of five weeks is then brought forward to the CEO, who enquires if the estimation is the absolute shortest time required to execute the task. Upon validation by the managers that the estimate is in fact the shortest possible execution time, the CEO adds a week buffer to protect himself and his company from any unexpected delays and or late-completion-penalties. The four week task thus becomes a six week task due to essentially, human nature.

It is this intangible, effectively immeasurable safety buffer that individuals incorporate into their time estimates that make it extremely difficult to successfully estimate the actual bottom-line time required to execute a specific task. The more management levels that are involved with the approval of the estimate, the more exaggerated the estimation becomes (Goldratt, 1997; Gold et al., 2013; Wright & Verlag, 2008; Van Heerden, 2013a). Since time estimates are generally based on a pessimistic personal experience, estimates are pessimistic and as mentioned before, more management levels translate into more safety, as each estimator protects their estimates from a global cut or from the ramifications of late delivery. Although it is clear that there exists vast safety time in most, if not all, time estimates as a result of people’s cautious nature, people actually believe their estimates are realistic. Often top managers are aware of this exaggeration trend and in an effort to counter it (to protect against the global cut), they reduce time estimations by a certain percentage, however this has become an industry trend and low-level managers anticipate this reduction in advance and budget for it in their estimations by adding further time buffer.

If it is considered that time estimates are so far exaggerated, then why do projects regularly, if not always, finish late? The reason could lie in the fact that there exists no reward for early completion in most projects, and if early completion is achieved, due to the deadline management styles used in most construction projects, there will be no advantage gained from this early finish since, the next scheduled activity will only begin on its original start date, regardless of the preceding tasks early-completion date. As a result early finishes are not reported, since that will lead to an expectation of conservative estimations in future, from management. “If you can do it once, then you can do it again”. Thus a scenario exists where contractors regularly delay or stagnate their own progress, in order to complete their task on the specified date. This is made evident by the numerous project schedules that register almost perfect schedule adherence on each individual task, a clear indication of a blatant delay and excess time resulting from a poor time estimate.

The result is that there is never any advantage gained from an early completion. The following task only starts on its scheduled date, not before. However, if a task is delayed beyond their scheduled completion date, that delay is thus passed to the next activity in full, whilst if an early finish is realised, no advantage will be taken thereof. In summation, in the current deadline approach to task scheduling, delays accumulate but advances do not. This leads to the concept of adding safety only where it is needed and not to each and every task. Instead of protecting individual task performance, such as would occur in the cost world, in fact the overall project performance is what is ultimately important to the success of the project (Goldratt, 1997; Zheng et al., 2014; Review, 1997).

TOC is based on the principle that there should exist a global buffer and not individual task buffers. This is radically different from what is currently the status-quo task scheduling in the construction industry. Could there possibly be potential in this methodology, that the construction industry could benefit from by implementation of TOC and critical chain management methodology?

2.5 Managing the Construction Company of the Future

The key to the successful management of a construction project may not lie in the implementation of a structured framework at all. The very nature of modern day management techniques and approaches are antiquated, the very same techniques and principles have been implemented for centuries and have remained relatively unchanged (Forbes, 2004). It stand true that modern-day construction projects have evolved in complexity, past the point where traditional management styles are able to effectively manage both resources and people.

People are no longer excited and motivated by the same drivers that motivated generations of the past, the management of human resources can no longer be successful in the new-world market by implementing outdated management philosophies. Could the key to successful management in the complex modern-day environment potentially lie in an entirely new approach to the principle and idea of management all together?

There is no doubt that the changing nature of both the economy and social drivers will inevitably change the way in which companies conduct business in the future (Spina et al., 2013). This may be a drastic change, where radical new ways of doing business are brought to the fore or possibly a more slight change, where certain aspects of the business world will change and others will not. These fundamental changes in the business world will require businesses to adapt in order to remain competitive in the new-world market. Despite these required changes that companies are required to make in order to adapt to the modern way of working, most if not all companies still employ an outdated management model. This model of organising and managing has been used and has remained virtually unchanged over the past 100 years. The model of organisation employed in today's management model involves coordinating activities through standardised rules and procedures, decision making on a top-down basis based on corporate hierarchy and people are paid to produce results without considering their other values. Hierarchal decisions enable an extrinsic, money based motivation system where objectives are achieved via linear alignment; a process whereby a predefined financial objective has been defined and committed to by a person in a position of power and each employee is given specific targets to meet in order to achieve the global objective.

There are two different views of how management will be conducted in the future which will be discussed in more detail, along with drivers of change in a later section.

How the Business World is Changing

According to *Julian Berkinshaw*, there are 4 major drivers of change, the first of which is "web 2.0" (Berkinshaw, 2013). This is the interaction between the internet and those of us that use it in order to conduct business. Traditionally the internet has been used as a form of reference, however, the new "web 2.0" era will see the coming to the fore of interaction between users of the internet and the internet, much like social media. Mobile information sharing will involve users commenting on content as well as sharing and creating new content on the internet in an interactive way, instead of using this content as a reference guide.

Another driver is "generation y", the millennial generation that is born after the year 1980. The "baby-boomer generation" and "generation x", those individuals born before 1980, have a very different approach to the workplace to that of the current working class, "generation y". Traditionally an older "generation x" or "baby boomer" employee would expect to get a job and remain in that position for an extensive period of time, often for their entire career, whereas the 'generation y' employee is technologically educated and expects to jump between different positions in different companies throughout their careers. This new generation employees also feel that their work needs to be of value to the company for which they work, they need to feel a sense of purpose. This generation of workers follow a very different set of values to those of older generations of employees and businesses need to keep this in mind when it comes to management of employees in the modern workplace.

A third and very important driver of change can be attributed to the emergence of developing economies such a Russia, Brazil, India and China. These markets bring with them a completely novel approach to the way in which business is conducted which challenges the norms of traditional western companies, one of the main drivers being lower costs. The fourth and last driver of change is sustainability, the creation of organisations that take care of the needs of communities and societies, as well as their employees of the future, in a manner in which is not to the detriment of the environment or future prosperity of mankind. The four discussed drivers of change outline the new strategic challenges for companies of the future that include being more agile, becoming more innovative and more adaptive to change and keeping employees engaged and motivated. These are the management challenges that face future companies.

As discussed earlier, although there are significant challenges facing the company of the future with regards to management, the management model from which the majority of companies operate is outdated. Decades of change has brought about three overarching so called "eras" in management as illustrated in Figure 2-18 and discussed in further detail below.

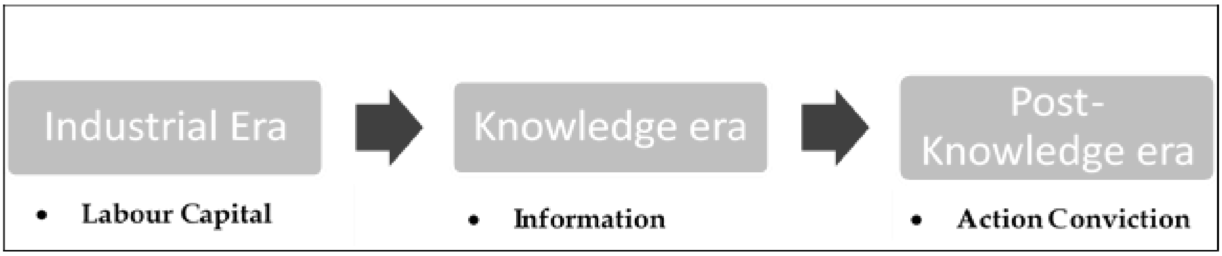


Figure 2-18: Progression of sources of competitive advantage in management over time

The Industrial era of management was the way of management in the past, the focus being on labour capital. During this era, labour was the scarce resource, motivation of employees was non-existent, people were just seen as a pair of hands and workers were alienated from the fruits of their labour. Moving into the current knowledge era where information is in fact the scarce resource and source of competitiveness for companies. Managers realised that workers do in fact care about their work, they can in fact think and contribute to the wellbeing of the company, via taking advantage of their abilities to think and should no longer be alienated from their work. In the knowledge era, companies look at the bigger picture, they consider what the customer may want, and employees' latent abilities are taken advantage of.

In the future we will move away from the knowledge era to a post-knowledge era, where neither labour nor information will provide a source of competitive advantage, collaboration will be key. This idea of collaboration is an underlying principle of SCM. In the post-knowledge era, there will be plentiful information but the source of competitive advantage will come through our ability to analyse and effectively use the information available to us, thus the scarce resource becomes our capacity, as human beings, to take the information we have and to make good decisions based on that information. Humans need to be able to take decisive action, since information will in the future not be such a source of competitive advantage due to the fact that collaboration and benchmarking will and is becoming the norm in businesses today. The source of advantage thus lies not in the scientific data but rather in the intuition and emotional conviction of the human being making the decisions. For example, purchasing a company that on paper is worth "x-amount", for an amount that is significantly larger than "x-amount", based on intuition, strategy, emotional conviction, gut feel and experience. No amount of financial analysis would have reinforced the decision to pay in excess of "x-amount" yet the action and conviction of the person, the human, who made the decision is where the source of competitive advantage lies.

A perfect example of this is the purchasing of "*WhatsApp"*, a free, advertising-free, messaging service for $ 9 Billion by Mark Zuckerberg on behalf of *Facebook*, a company that essentially has no value and no direct income potential (Warman, 2014). This company was purchased for reasons other than financial logic. Such an acquisition would never have been possible in the industrial or knowledge era due to the constraints placed on employees by traditional management structures. Thus, as discussed before, the past and current management models are no longer fit-for-purpose due to the fact that the management of people on a personal level has failed.

Workers in a Company; the Management of People

A study by *Attarzadeh* supports the viewpoint that the underlying problem of the failure in management is the fact that management is seen as a tool to maximise and enforce employee discipline, standardise work, develop routines and organise and simplify complicated problems, whereas modern management needs to be agile, innovative and engaging in order to be successful (Attarzadeh & Ow, 2008). Thus, modern management models need to be restructured and there needs to be a shift in overall management practice, achievable by exploitation of new ideas, deployment of new products and innovative services and involving new ways of thinking into the management of businesses. Businesses need to become more experimental and adventurous in the way they do work and in the way they get work done through other people according to *Berkinshaw* (2013). There exist extreme management principles, such as avoiding managers completely and allowing accountability and power to rest solely with the employees, but this will not be discussed further since it is not a viable option for the construction environment, where many decisions need to be made by individuals with a certain degree of insight and education.

In the post-knowledge era, managers need to be the implementers and empathisers within the company, they no longer need to be the traditional monitors and controllers, nor the information conduits or experts that managers are in the vast majority of companies today. Today's business is all about getting the most out of people and trying new, innovative ideas, whilst still evaluating both old and new ways of thinking. One of the most important changes that companies need to make is with regards to how they motivate their employees.

Traditional management approaches make use of extrinsic motivation such as material drivers such as salary, turnover percentage bonus and sales incentives. Future management will focus on social drivers and personal drivers as sources of motivation, instead of material drivers alone. Personal drivers focus on the needs and wants of the human being and are completely intrinsic, meaning that they cannot be physically measured nor can they be quantified, this will differ from employee to employee. Social drivers are a combination of extrinsic and intrinsic motivations, for example, "if you design this valve, you will get R 1000 and you can call it a name of your choosing". Another example of taking advantage of intrinsic motivation is allowing flexible work hours for employees, where employees can decide their individual work hours and place of work, for example; working from home instead of reporting to a centralised office each day. It is the responsibility of a manager to find the correct combination of motivation for each individual employee, in an attempt to facilitate the shift in thinking from extrinsic motivation to intrinsic motivation.

2.5.1 Rethinking the Role of Management

The two major points of view of what the future of management will be are: there will be a dramatic change in the manner in which management is conducted; or there will be no significant changes and management will continue to be practiced as it has been for hundreds of years, despite the forces driving the need for change. The outcome of as to what form of management will prevail in managing the company of the future will depend to a large extent on the approaches that managers and corporations adopt in the management of their employees.

Employees are all human beings and are thus motivated when either the work that they are engaged in is challenging, they have freedom to do work in their own way, there is value or importance in the work which they do and when working with colleagues that they like. Management is essentially a process of enabling employees to do their best work whilst remaining engaged and motivated. So in the modern company, the role of a manager will no longer be focused on being a monitor and controller, but rather on being an empathiser and implementer whilst maintaining the role of information conduit and qualified expert. Thus the softer elements of management are becoming more important in the modern business world. Along with this shift towards a softer approach to management is the need to change the way in which work is being conducted in the workplace. Since time is a restriction for all managers (a day is only so long), in order to maximise the value that can be gained from a task, there needs to be a conscious effort to spend the time that managers have on the tasks that translate to the most value for the organisation.

The challenge is then how to change the way in which people work. Knowledge workers, according to the *Harvard Business Review,* spend their time as illustrated in Figure 2-19. According to an article by *Berkinshaw*, as much as two thirds of a managers' time is spent on desk-based work and meetings, these are tasks that can be easily delegated to other less strategic employees in order to free strategic employees to conduct more important, value-adding work, the work that matters (Berkinshaw, 2013). Managers are generally wrapped up in commitments and red-tape activities that restrict their ability to perform. Instead of their attention being focused on critical tasks, frequently managers are found to be conducting routine, often mundane tasks that are not benefiting the company, nor do these tasks need specialised skills to complete. Thus there could be an initiative to attempt to delegate the non-value adding tasks that are extremely time consuming, as well as easily off-loaded, to subordinates within the company, even if that may require a restructuring or hiring of new staff. The time that will be saved on the part of critical employees such as managers will be spent on critical, value-adding tasks that cannot be delegated to lesser-skilled employees. This will lead to an improved productivity of managers and will ultimately far offset the incurred extra cost associated with the delegating of non-value adding tasks to other employees, such as an increase in the number of employees.

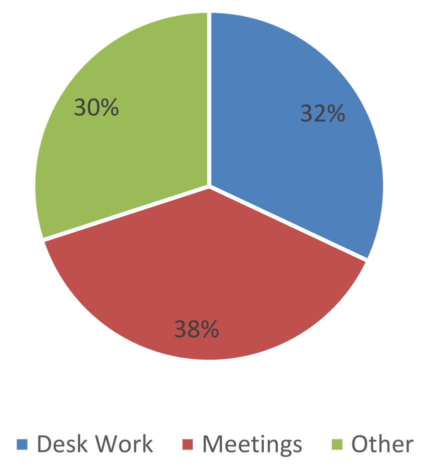


Figure 2-19: Time spent on various office-based activities (Berkinshaw, 2013)

The underlying idea is to ensure that a company's primary resources need to be able to perform at their optimum wherever possible in order to translate the maximum value from the minimum effort. Why then is this not happening in businesses today? The answer is a combination of old habits as well as a reluctance to change on the part of the employee.

A solution to this problem could be to first identify low-value tasks and then from these tasks, decide which tasks can be delegated to others, disposed of completely or redesigned and changed in order to make them more value adding or intellectually stimulating. Once tasks have been identified, employees need to act on this commitment to delegate, redesign or dispose of tasks by "off-loading" these selected low-value tasks. Once the employee has committed, the free time that is accumulated as a result of this process must be reallocated to value-adding tasks. This will, in theory, result in more effective management of value-adding, critical tasks which should in turn translate into a higher productivity and thus improved performance of the company as a whole.

2.5.2 The Company of the Future

The factors discussed in the preceding sections make it clear that there is an undoubted shortfall in the management techniques employed by the vast majority of companies today, what then will the company of the future be like? This section will focus on the company of the future, not on the individual manager or individual management styles. According to *Berkinshaw*, there will be a shift in two major areas; ownership and organisation, these are discussed in more detail below.

Ownership of companies in the twenty-first century is generally structured according to the limited liability corporation (PLC). This form of ownership is employed by the vast majority of corporations, including *Company A*. The public limited company (PLC) is a category of ownership in the form of a legal entity that separates owners and employees from the entity, ring-fencing assets and liabilities of the company, in order to protect investors and stakeholders from personal financial harm as a result of poor company performance and or insolvency. This is the default ownership model in use today for management of capitalist commercial enterprises.

One of the major problems associated with a PLC is that there is an inherent drive to retain share value due to the scrutiny and expectations of the public and the media. There is thus a focus on short-term goals that is supported by narrow thinking on the part of management. The model aims to satisfy the shareholder by making short term decisions, based on short-sighted management principles that are ultimately not to the long-term benefit of the company. This cannot be a successful ownership model for the dynamic company of the future. As a result, it is expected that the company of the future will follow alternate forms of ownership such as:

- private equity ownership, where a company is owned through a holding company
- family owned companies, owned entirely by family members
- the co-operative ownership where suppliers own the company
- trusts, where shares are managed by a board of trustees
- or a partnership, where a number of partners collectively own and share the company.

These alternative models of ownership provide a long-term model of governance that facilitate long term growth and are not subject to the pressure for short-term results that PLC's are and are thus proving to be more attractive models of ownership for the company of the future. Since *Company A* is a PLC, this point is of tremendous significance.

The organisation and structure of a company of the future is expected to be focused on lateral organisation. There will be a drive towards decentralisation, as well as networked organisational structures that focus on a bottom-up approach to management. This organisational structure will in turn lead to a situation where employees will no longer be full-time employees but rather individual, autonomous contractors. There will be an increase in the prevalence of freelance contractors that will serve larger companies on a contractor basis, thus eliminating the need for companies to employ thousands of full-time employees. This notion of a freelance employee is not dissimilar to what was discussed earlier, where it was argued that the employee of the future will want a variety of jobs throughout their career that will allow them the freedom to choose what they want to do and where they want to work. Work-automation and the ability to do work remotely and from an off-site location that is brought about by technology allows employees to work with greater freedom. This is a primary reason why employee relationships in the company of the future will be different from traditional companies of the twenty-first century, where salaried full-time employees are common and independent contractors and consultants are the exception rather than the norm.

2.6 Chapter Overview

This section provides a short summary of the key concepts and conclusions from literature. The current state of the South African construction industry

2.6.1 Supply Chain Management

Applications of SCM within the manufacturing sector have resulted in significant savings, both in supply chain costs and by improving customer service levels. Project based organisations failed to implement SCM concepts and strategies in early years such as what was the case in the retail and manufacturing industries and as a result are still developing SCM techniques to improve their supply chain processes in an effort to gain significant competitive advantage in the market. According to *Venkataraman* there exists evidence that there exist significant opportunity for construction firms to reduce operational costs by eliminating non-value-adding activities such as time spent on waiting for approval or for materials to arrive on project (Venkataraman, 2004). There is evidence from literature that suggests the construction industry could potentially benefit from significantly improved supply chain operation as a result of a concerted effort by industry to adapt and improve their supply chains.

2.6.2 The SCOR and BSCOR Model

Both the SCOR and BSCOR models are structured frameworks with predefined metrics and processes. These metrics and the three different level processes of the models are used to measure and map supply chains. A number of attempts have been made to implement the SCOR framework within the construction industry, specifically for effective management of projects. The fundamental flaw of the SCOR model, when considering the plan processes of the model, is that the model considers a single-company planning process. This implies that there is no consideration of the effect that subcontractors and contractors may have on the overall production, or in the case of construction, the construction process – there exists a lack of synchronisation between SCOR and construction.

Since more than one company uses the same location, the construction site, for production, planning and sourcing they too have an effect on the overall production, not exclusively the main contractor. Upon evaluation of the information stipulated above and in section 2.2.3, the SCOR model simply cannot, in its current form, be implemented in the site-based construction industry. However, there exists a specialised framework, the BSCOR model that is being specifically developed for use in the construction industry. This structured framework may hold true potential for addressing the misalignment of the SCOR model and construction by successfully accounting for synchronisation of contractors and subcontractors into the framework structure.

The BSCOR model has yet to be completed but once completed, such a model may prove instrumental in changing the manner in which construction processes are planned, executed and managed. Such a model may ultimately allow effective control of budget spend on such projects while limiting schedule delays through effective supply chain planning and coordination by providing a single universal standard for managing projects, other than conventional project management as per PMBOK.

2.6.3 Defining a Construction Project and it's Supply Chain

By definition, a construction project is a temporary event and as such there exists no permanent supply chains for each specific project. Because construction projects are limited in time, and located at diverse locations depending on the project requirements and as such it can be said that each construction project is unique. Such a temporary supply chain only produces once-off, engineer-to-order projects through continual reconfiguration of project organizations that separates the design and construction aspects of the project. This separation is detrimental to process and information flow and limits collaboration and effective communication between stakeholders.

Non-temporary or permanent supply chains, have clearly defined goals, contingency plans, develop coherent relationships with suppliers and contractors and often produce a similar product or range of products. This is unlike temporary projects where each project entails unique product development and unique circumstances and complexities. This complexity is further exacerbated by the number of contractors nod subcontractors who are involved in the project. For example, if a sub-contractor is delayed, this delay is transmitted through the whole project.

The unique nature of a construction site entails the establishment of new vendor- and sub-contractor relationships for each project. As a result, the company that manages a temporary supply chain production, such as a project, will often outsource activities that are non-vital to subcontractors and consultants.

2.6.4 The Current State of the South African Construction Industry

The South African construction industry faces a number of challenges, although each project may face unique challenges, the general overarching challenges facing the industry at present are listed and briefly discussed in Table 2-12.

Table 2-12: Obstacles faced by the South African construction industry (PWC, 2013; Treasury, 2015; Ofori et al., 1996)

	Obstacle	Description
1.	**Poor planning phase execution**	Most if not all construction projects suffer from a horrific lack of planning. This originates as early as the pre-feasibility stage of project planning and propagates and intensifies the more advanced the stage of planning is.
2.	**Design errors**	Poor planning and an industry possessing a mediocre skill level results in design errors. It seem trivial that after a certain amount of experience, designs may become second nature. However, this is not the case and project designs regularly suffer from errors as a result of negligence or lack of experience.
3.	**Scope change**	Scope change is possibly the single greatest issue in the construction industry and contributes to the majority of budget and schedule overruns. Often inadequate planning of a certain task will result in scope changes during project execution.
4.	**Rework**	Scope change inevitably results in rework. It is not uncommon for a structure to be rebuild two or three times, either due to inferior workmanship or due to changes in scope by the client, architects or engineers. Such unplanned changes fall outside the scope of approved tenders and often lead to claims and even arbitration as contractors and clients argue over budget and schedule claims.
5.	**Contracts selection**	The results of rework and scope change, such as contractor claims, can often be mitigated by implementation of the correct contracting model during project inception. There exist a vast array of contacting models, each lending itself to a certain project situation. Certain construction may be effectively managed by certain contacting models and not by others, this needs to be considered before the tendering process is initiated. Correct contractual agreements will limit conflicts and claims and will ultimately be of benefit to all stakeholders, as risk and reward will be clearly and legally defined.
6.	**Procurement and contractual management systems**	Similarly, procurement is often not managed correctly. The use of e-procurement is the future of procurement and should be implemented wherever possible. However, it should be noted that the value of and need for personal relationships can never be underestimated in the construction industry. Contracts management software is essential in the modern construction industry and needs to be considered as essential for any major company. Such software is capable of monitoring the performance of various supplier, partners, customers and employees. Results of effective contracts management range from the structuring of profitable deals to avoiding penalties to ultimately realising revenue more quickly.
7.	**Subcontractor management**	Effective management of subcontractors relies on the collaboration of many personnel operating in many different disciplines. Effective management of subcontractors spans all phases of contact life, from inception to close-out where

	understanding the constraints and drivers of the subcontractor is of vital importance. The performance of subcontractors is critical to any construction project and thus subcontractors need to be managed both on a technical, organisational and business administration level. Effective management is centred on implanting the correct contracting model and documentation, this ensures that all parties know what their responsibilities entail and what their scope of work is.
8. Understanding risk	Understanding risk is of the utmost importance to the success of any business entity. Risk in projects is what guides and incentivises contractors and subcontractors in their tenders. The risk profile of a certain activity should determine the value of a tender, this evaluation and quantification of risk is where the vast majority of contractors lack experience. Risk evaluation is a business skill, not a technical skill. The vast majority of contractors, especially HDSA-owned firm that have only been active in the market for a few years are not equipped to effectively deal with such complex economic evaluations, which results in "thumb-suck" tenders based on inaccurate risk evaluations. As a result, such tenders do not prove realistic and either the contractor is severely punished by means of penalties or the client and contractor share the loss, ultimately resulting in a budget overrun, schedule delay, or both.
9. Project complexity	How a firm anticipates, understands and mitigates the effects of complexity governs the success of both a company and project.
10. Resource loaded schedules	A schedule without allocated resources in any other industry other than the military, is "a recipe for disaster". A non-resource-loaded-schedule provides no insight into the availability of resources in relation to time. For effective resource allocation and scheduling in a project environment, schedules need to have allocated resources.
11. Schedulers and planners	Projects require dedicated, qualified schedulers and planners in order for plans and schedules to be realistic.
12. BEE programmes	BEE and other affirmative action programs are an essential part of the development of South Africa, however, such programs need to be correctly implemented, monitored and controlled in order to ensure such programs achieve their goals of redistributing wealth to previously disadvantaged communities and not to a handful of influential black businessmen and politicians.
13. South African politics	The unstable nature of South African politics, coupled with the outrageous level of corruption that is prevalent in both local and provincial government deters international investment and throttles economic growth.
14. Intrinsic motivation	Employee motivation is no longer solely based on the amount of money that they earn. The modern-day employee seeks a job that is intrinsically motivating, a job that is challenging, exciting, self-fulfilling and safe.

2.6.5 Conventional Project Management

Project Management is not just a technical skill, an extremely important part of project management is very much about the type of person who is a project manager, their people skills, communication skills and leadership abilities as a person. Even if an individual is able to plan a project, there is no guarantee that they will be able to manage that project because they may lack the ability to manage people. Project management is the process of balancing competing project constraints while addressing the concerns and expectations of stakeholders by applying applicable management principles and processes.

A project is a temporary endeavour that has a beginning and an end, creating something that is unique by involving single or multiple individuals or organisations. Most projects are constrained by either money or time, depending on the requirements of the specific industry, the identification of which is important as trade-offs between time and money need to be made. The majority of projects are managed by making reference to the *Project Management Body of Knowledge* (PMBOK). Recognised as the global standard for project management, PMBOK guide identifies and lists best practices and techniques for overcoming challenges and managing projects. This standard is constantly updated as the realm of project management progresses and helps to provide a standard terminology/language for project management.

Projects can be broken down into four rudimentary phases, starting, planning, performing and closing.

The starting phase is concerned with defining why a certain project is being executed, formally authorising the project, appointing a project manager and developing a project charter. This an area that is often neglected by project managers, resulting in stakeholders not understanding the requirements or value of the project that regularly results in delays later in the project. By involving project managers in this phase of the project instils a sense of pride and ownership in the project management of such a project as they understand the reasoning and importance of the project. The project charter is a means to communicate project objectives, success criteria and schedule and budget milestones to all involved in the project in order to justify the project.

The planning phase is the detailing phase of the project where it is decided what is to be done, who is going to do it, when will it be done by and how it will be done. The various assumptions and constraints are identified and managed accordingly. If there is insufficient planning, there will be a lack of control later in the project, thus planning is extremely important for project success, the importance of which should not be overlooked.

The performing phase is the phase where the actual execution of the project tasks take place. This process is managed by means of a comparative study between planned performance and actual achieved performance, it is all deadline orientated. Each task has an allocated start and end date by which the task is controlled. If a task is delayed, there is a knock-on effect on the following task. Project management controls the subsequent delay of tasks by means of the critical path management strategy and sometimes a more industrial approach, critical chain management. In projects managed in a conventional manner, each task is managed individually, protecting each individual task deadline where in a critical chain situation, the project deadline as a whole is protected, this is discussed at length in section 2.4.7.

The closing phase is an important phase for any project as this is where lessons are learnt that improve the management of future projects. The close-out phase involves documentation of the lessons learnt, filing of all project documentation and release of project resources. It is important to determine what worked and what never worked with regards to problem solving, change management, contractual agreements and management techniques. More importantly, the scope of the project needs to be validated in order to ensure that everything that needs to be done has been done and signed off.

There are three categories of role-players in projects, the sponsor, the project manager and the team who work together to achieve the desired outcomes of a specific project.

Conventional projects involve defining a scope of the project along with a Work Breakdown Structure (WBS), communication matrix or communication plan. The project execution is driven by the concept of Earned Value Management (EVM). EVM is a project management technique that is commonly used in construction projects to measure the performance and progress of a project or task in a project by comparing the scheduled work with the completed work.

2.6.6 Managing the Company of the Future

Due to the changing nature of the business world as well as the shift in personal drivers of employees, consideration needs to be given to the future of management.

The management of company of the future could be based on a combination of traditional management practices that work and will always work, a as well as new innovative management practices that are better suited to the dynamic business world of the future. Management of employees is expected change drastically, from extrinsic motivation to intrinsic motivation.

Chapter 3. Research Design and Methodology

This chapter serves to present and discuss the specific research approach, objectives and data gathering and analysis procedures used to resolve the research problem delineated in *Chapter 1*. This chapter also presents the data obtained through both qualitative and quantitative research methods during the case study process.

3.1 Research Aims and Objectives

It is important to momentarily reconsider the research aims and objectives that were presented in *Chapter 1* before discussing in detail, the research methodology and data analysis techniques.

The aim of this research is to evaluate whether a Supply Chain Management (SCM) approach to managing construction projects will be more effective than conventional project management techniques, and to highlight key project management processes and metrics based on experts' feedback and actual experience of working on a real-life project.

The purpose is to gain a more in-depth perspective of as to what commonly goes wrong in the management of construction projects and to compare it to SCM methodologies and principles from literature. This alternative (SCM) perspective of project management will serve to bridge the gap between current project management and SCM in the construction industry in an attempt to find a superior way of managing projects.

3.2 Data Gathering

3.2.1 Techniques

The proposed research approach will consist of a comprehensive literature review with specific focus on both Supply Chain Management (SCM) and the construction industry. The research design methodology will follow the process outlined in Figure 3-1 and should be evaluated with reference to Figure 3-3 in section 3.2.2.

All measurement and data collection procedures were based on systematic observation, thus the results and techniques implemented in measurement and data collection are considered to be replicable (Welman, 2005).a

A set of informal and formal interviews were conducted throughout various levels of management within *Company A*, implementing a semi-structured interview style. A semi-structured interview comprises of a set of themes and questions, also known as an interview guide, that the researcher makes use of in order to direct the specific discussion in a particular direction, based on the outcome of the discussion and depending on the interview candidate. Such an interview style is considered preferable to a structured or unstructured interview style, on the basis that vague responses and off-topic discussions are limited (Welman, 2005).

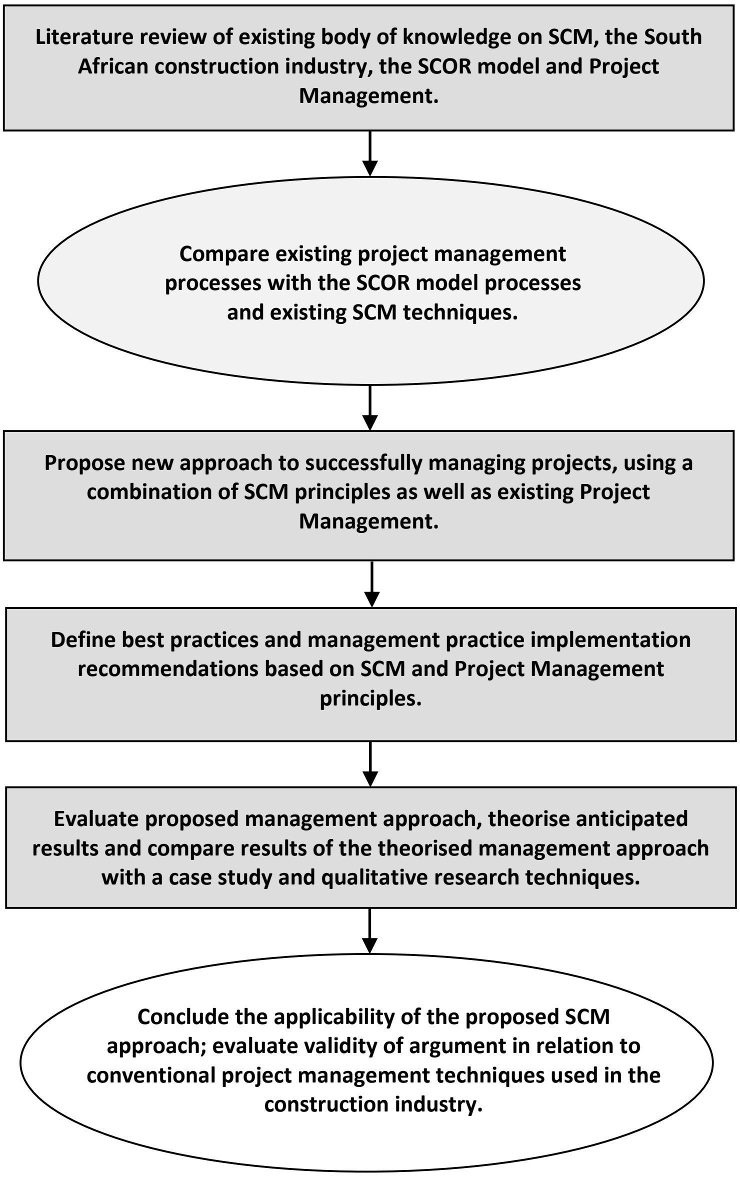


Figure 3-1: Proposed research design methodology

Interviewee selection was based on the *snowball sampling* technique of candidate selection. According to *Azim*, *snowball sampling* provides an extremely accurate insight into a discussion topic, especially in the case of qualitative research such as the research involved with this study (Azim, 2010). Further, such an interview technique allows for a high candidate response rate and is effective in limiting unqualified responses from interviewees due to the personal nature of the interview. Since the topics that are to be discussed are of a sensitive and confidential nature as well as the fact that respondents are from different backgrounds, a semi-structured interview was considered to produce accurate and qualified data.

The external validity of the study is directly related to the validity of a generalization founded on the findings of the research. The external validity or "approximate truth" of suggestions, inferences, or conclusions made during the course of this study can be considered acceptable, based on the fact that the case study was that of a construction project, in the South African mining environment and that is managed using conventional project management techniques. Interview candidates can be considered to be representative of the population based on the fact that all candidates have experience in the South African construction industry and in project management.

Based on the evidence presented above and the limitations of the study, discussed in section 1.8, it can be concluded that the findings of this study can be considered relevant for other construction projects in other locations within South Africa and at other times.

3.2.2 Procedure

The proposed research process for this study will follow a structure as outlined in Figure 3-2 while a more detailed overview of the logic of the study is presented in Figure 3-3.

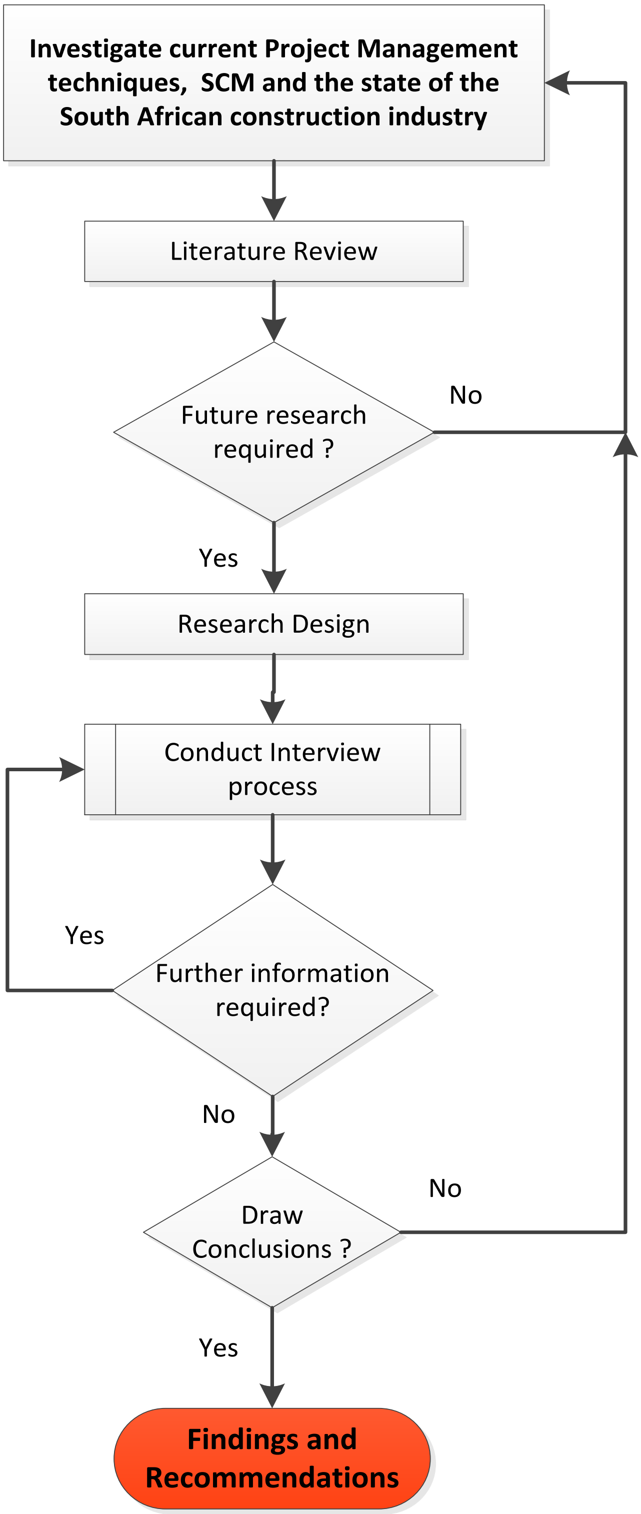


Figure 3-2: Proposed research process

This study consists of two phases, the first phase is descriptive in nature and involves identifying problems that persistently occur in the construction industry, with specific reference to the South African construction industry. This identification of problems was achieved by an in-depth literature review and by means of a case study. A case study was conducted at a single company, *Company A*, on a single project, referred to as the WLDC project.

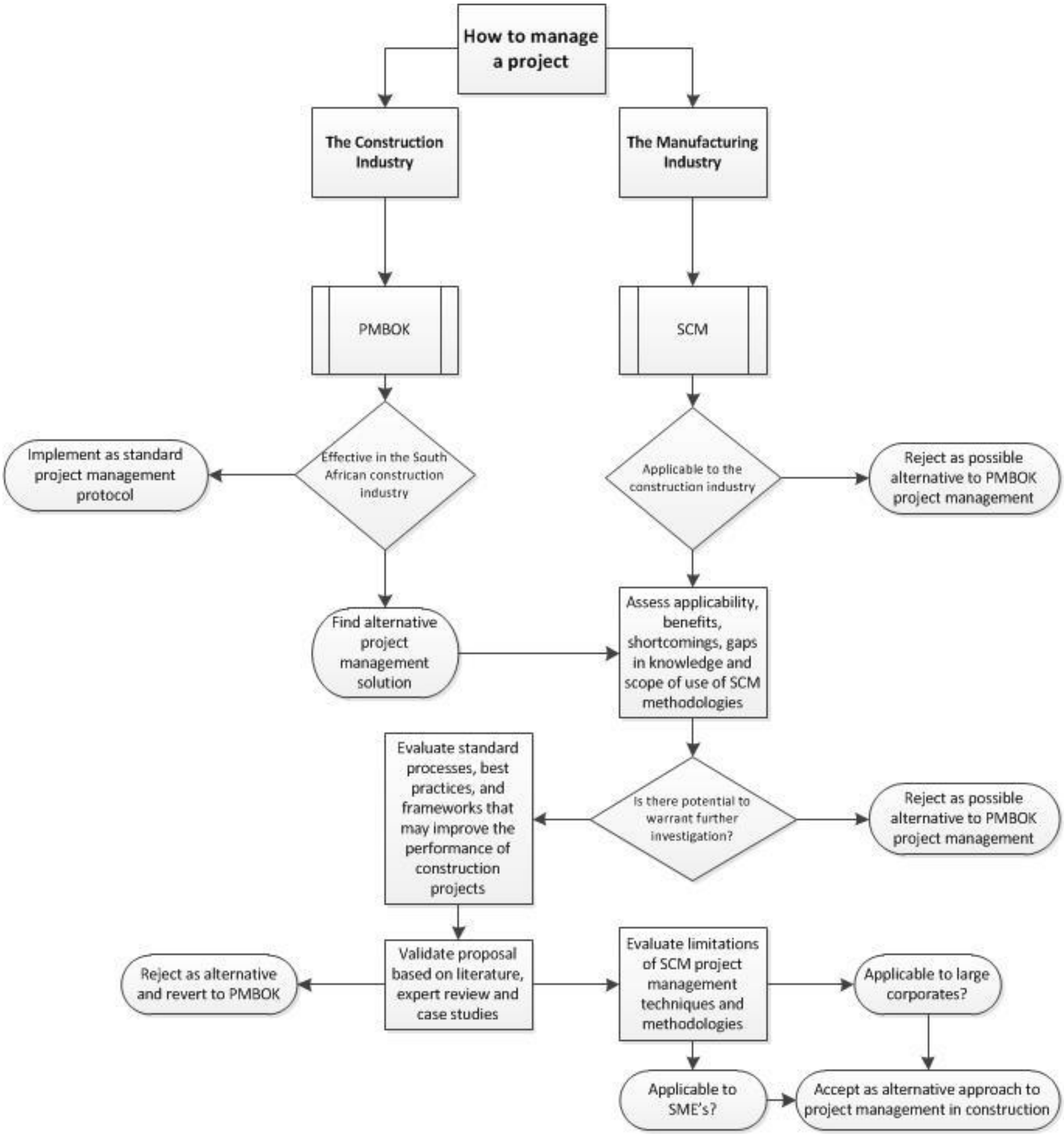


Figure 3-3: Logical flow of research

The second phase of the study was to validate the findings of literature. The case study was predominantly used as a verification-reference in order to confirm the findings of the in-depth literature review. Furthermore, the case study was used to gain an insight as to the practical difficulties that occur in an on-site environment as well as to assess the technical hitches and implications on the project as a whole. Based on the project data that was analysed and qualitative data that was gathered via discussions and interviews, the management team, main contractor and economic conditions of the case study are considered representative of large projects in the South African construction industry. Thus it can be concluded, as discussed earlier, that such a case study is suitable for this kind of study.

The selection of a case study project was particularly important as the findings, internal and external validity and conclusion of this study are directly influenced by such a case study. It is imperative, then, that such a project be selected so as to be able to generalise the findings of such a study. The WLDC project was selected due to its managerial structure, contract value, and socio-economic issues and due to the fact that *Company A* was willing to divulge this extremely confidential intellectual property, thus facilitating somewhat easy access to data, managerial employees, and participating third party companies.

With regards to the data gathering procedure, three central methods were implemented in the data collection process, a series of both formal and informal, semi-structured interviews, numerical data analysis as well as direct observations from the site and from a progress meeting.

By means of data collation and cross referencing, numerical data was able to help classify commonly occurring problems while the interviews and on-site discussions were used to determine the root cause of such problems and evaluate to what extent they affect the construction project as a whole. Candidate selection for interviews and discussions were based on the framework outlined in Figure 3-4.

All candidates interviewed during the case study were employees of *Company A*, either in a consulting capacity or direct employees. All of whom have experience in the construction industry and have all been involved in a construction project in a managerial capacity and in addition to construction experience, have experience in the mining environment. Not in actual physical mining operations but in the “mining corporate world”. This is a point of importance, since the mining industry poses unique financial and socio-economic challenges that are not as regularly encountered in general the construction industry.

Further interviews were conducted to further validate the findings of both the literature study and findings of the case study. This validation was in the form of expert review and comprises of five expert reviews (*Appendix B*).

This added degree of complexity requires feedback that is of a specialised nature. Feedback from interviewees that have not got experience dealing with such challenges could contaminate data, thus a concerted effort was made to select candidates with a certain degree of experience in both the "mining corporate world" and in management of South African construction sites.

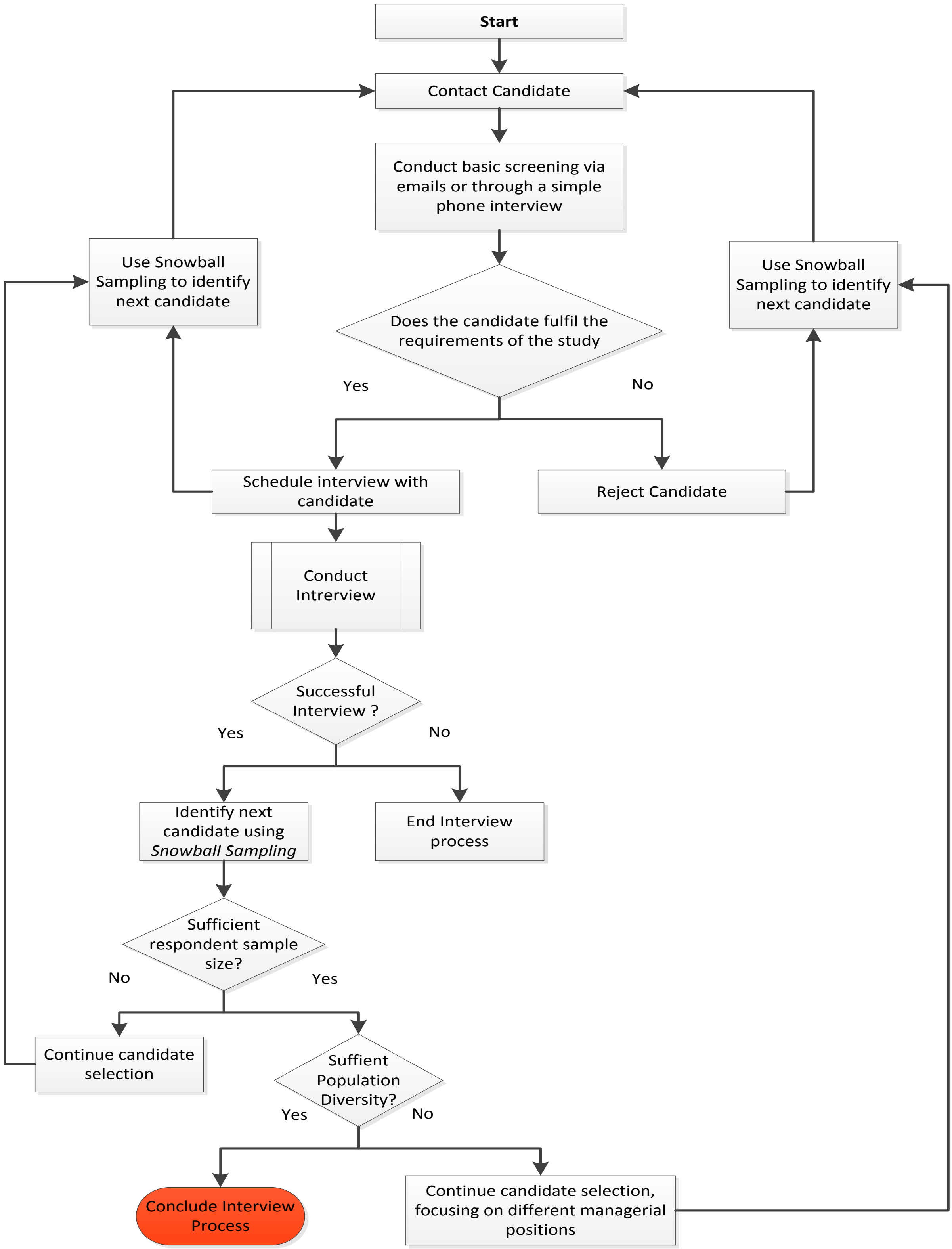


Figure 3-4: Interview and candidate selection process

3.2.3 Identification of Discussion Themes

The selection of discussion themes was structured and tailor made to direct the conversation in the direction of the intended research. The topics that were the focus of both the structured interviews and informal discussions are listed in Table 3-1. Interview candidates were asked questions that directly or indirectly covered a specific topic of discussion in order to thoroughly investigate the status of the specific project, schedule delays and the reasons behind them as well as the associated budget implications thereof.

Table 3-1: Interview discussion theme rationale

Topic of Discussion	Reason for Selection
Personal biography	To develop a profile of the candidate to evaluate adequacy for study. To interact on a personal and social level with the interviewee.
Summary of project	To establish an overview of the project as a whole, in relation to other operations, the economy and to evaluate specific challenges and issues unique or common to a specific project or class of project.
Personal responsibilities	To understand the complexities and challenges faced by the interviewee. This helped categorise the management role of the candidate as well as to evaluate the strategic importance of the decisions he/she makes in relation to the project as a whole.
Challenges facing the project	To get an "official" overview of the problems encountered in the project and the formally stated reasons behind them.
Reasons for challenges and issues	To identify the root-causes of problems and challenges and to identify their relevance to and effect on future projects.
Recommendations for similar future challenges	To establish a theoretical solution to each problem from experienced individual with on-site experience.
Specific issue elaboration	To get an in-depth rational as to the problem, its causes and the knock-on effects of the specific problem with regard to cost and schedule.
On-site politics and dynamics	To evaluate the problem solving culture and accountability of the company and on-site personnel.
Personal opinion of project status	To ascertain a corporately untainted opinion of on-site issues, their causes and the effects thereof on project success.

3.2.4 Identification of existing knowledge overlap

The identification of similarities between the PMBOK and SCM knowledge areas is considered an objective of the study. Figure 3-5 presents the overlap in existing knowledge between construction project management and SCM. This topic is discussed in more detail in *Chapters 5, 6 and 7.*

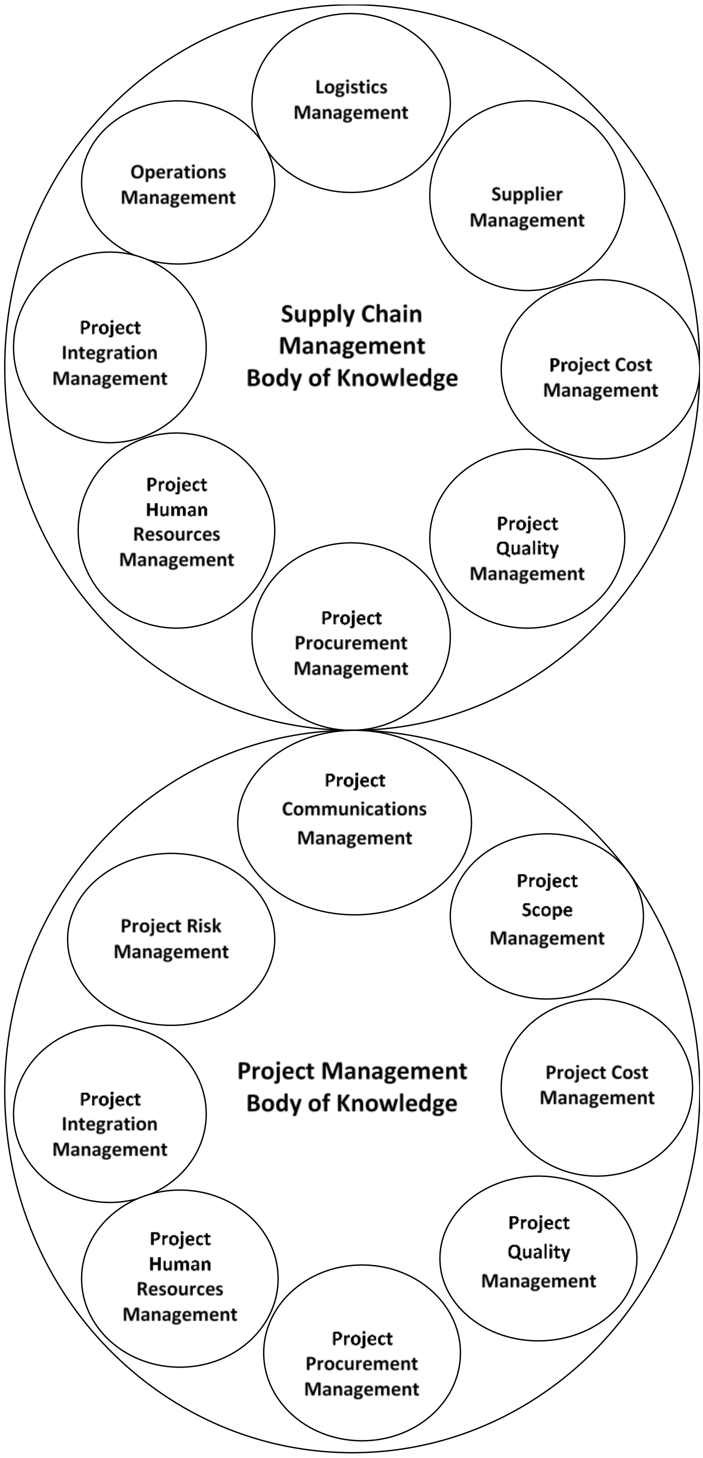


Figure 3-5: Existing knowledge overlap - Adapted from: (Project Management Institute, 2008)

3.3 Case Study - WLDC

3.3.1 Project Overview

Company A has several mining operations in a certain area in South Africa, all located within a one hundred kilometre radius of one another. *Company A* has decided that their mining operations require a centralised distribution warehouse to be used for spares management. For the sake of anonymity the warehouse shall be referred to as WLDC. The location of the WLDC is near an existing railway line siding and is well situated with regards to main transportation routes and existing operation in the immediate vicinity of the facility, illustrated in Figure 3-6.

Figure 3-6: Orientation of WLDC with respect to nearby operations

The distribution center will provide service to both the mines and process plants in the immediate area. The WLDC will serve as the main Hand-Over Point (HOP) for all the operations in the area, however, some direct deliveries will still be applicable for site specific materials or where double handling is to be avoided. The WLDC facility will be strategically replenished directly from suppliers as well as serving as a *Cross Docking* Facility. The facility will cost R145 million once completed, the completion date of the facility is expected to be in August 2015. The cost breakdown is as follows: R

120 million original contract value, a voted upon extension of R20 million in April 2014 and an additional extension of R5 million in May 2015.

According to *Chung*, "before modernizing their operations, manufacturers should first modernize their supply chain and logistics processes in order to optimize prospective investments". *Company A* has adopted a similar outlook in their planning and have thus made this development a strategic one. Once completed the facility is expected to revolutionise the antiquated supply chain that is currently in operation within *Company A.* The modernised facility will streamline and optimise supply chain operations by transforming antiquated inefficient processes into integrated value chains.

This is explicitly evident by the projected payback period of the project which is expected to be only 2.2 Years. The project shows a total savings of R212.9 million over 5 years, excluding an indirect savings of a further ZAR 95.2 million. Furthermore, the facility is expected to have a Net Present Value (NPV) of R54 539 008 and Internal Rate of Return (IRR) of 64.62% after five years, calculated on a discount rate of 11.5%. This is considered to be a good investment by any assessment perspective and in any industry sector.

Presented in Table 3-2 are the key project milestones associated with the WLDC project. Figure 3-7 serves as a summary of technical specifications and considerations imposed on the WLDC project.

Table 3-2: Key project milestones

Deliverable Description	Planned End Date	Forecast End Date
Site Establishment	28 Feb 2014	Completed
Earthworks	30 May 2014	Completed
Civil Work Completion (Slab & Buildings)	25 Nov 2014	Completed
Steelwork and Sheeting	10 Dec 2014	20 Feb 2015
Completion of Main Works	15 Dec 2014	21 May 2015
Completion of IT	30 Dec 2014	25 May 2015
Completion of Security Camera's	30 Dec 2014	30 May 2015

The WLDC will serve as a strategic facility for *Company A's* regional operations.
The need for the WLDC was further reinforced by evidence brought forward to *Company A* by an independent inquest by the Boston Consulting Group (BCG) as part of their proposal to improve costs and efficiencies within *Company A's* operations.

Figure 3-7 serves as a summary of technical peculiarities, specifications and considerations imposed on the WLDC project. *Company A's Supply Chain Department* will maintain the right of beneficial occupation as of mid-May 2015 after which handover will take place and fulltime operations will commence on an incremental ramp-up basis.

Design: • Rezoning in places • As per Architectural design	**Engineering:** • Structures and facilities according to SANS and SABS codes of practice
Innovation: • Using laser technology and pre-cast concrete columns to save time	**Strategy:** • Maximize local participation • All contactors CIDB accredited

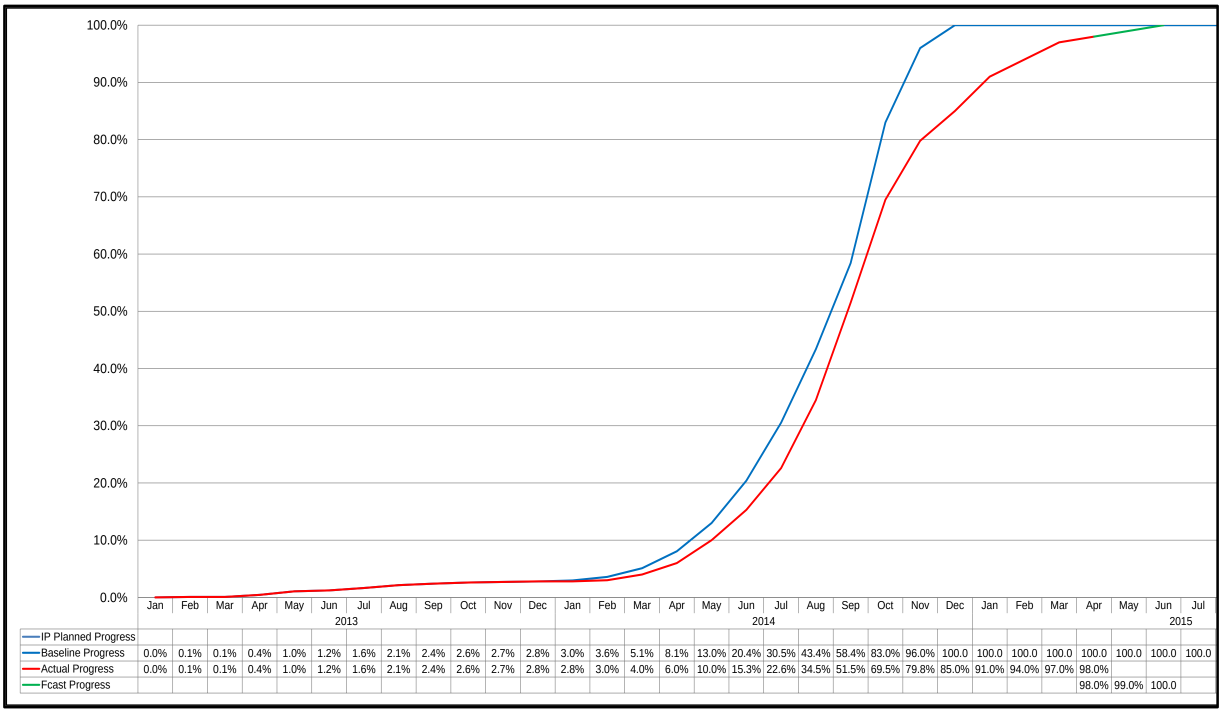
Figure 3-7: Technical Specifications and considerations of WLDC

3.4 Data Analysis

3.4.1 Project Schedule Performance

For the sake of this schedule analysis, the pre-planning and planning phases of the project will be ignored.

Project implementation started in March 2012 after which approval form *Company A's* executive committee was finalised as of August 2012. The project was scheduled to be completed by no later than January 2014. In October 2012 the project was deferred for 2 months due to *Company A's* financial constraints. The project was taken out of deferment in mid-December 2012, whereby full commencement was to start in January 2013 as illustrated in Figure 3-8 while Figure 3-9 and Figure 3-10 provide a more detailed comparison between the planned baseline progress, actual progress and future forecast progress.



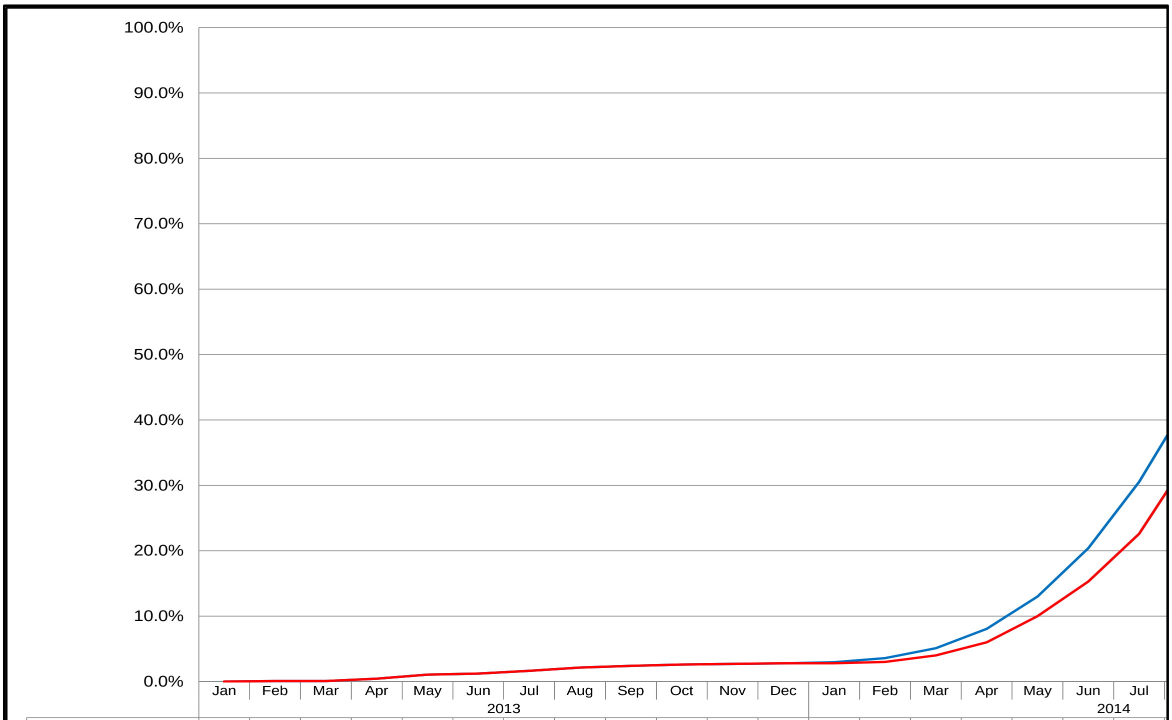
2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IP Planned Progress												
Baseline Progress	0.0%	0.1%	0.1%	0.4%	1.0%	1.2%	1.6%	2.1%	2.4%	2.6%	2.7%	2.8%
Actual Progress	0.0%	0.1%	0.1%	0.4%	1.0%	1.2%	1.6%	2.1%	2.4%	2.6%	2.7%	2.8%
Fcast Progress												

2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IP Planned Progress												
Baseline Progress	3.0%	3.6%	5.1%	8.1%	13.0%	20.4%	30.5%	43.4%	58.4%	83.0%	96.0%	100.0
Actual Progress	2.8%	3.0%	4.0%	6.0%	10.0%	15.3%	22.6%	34.5%	51.5%	69.5%	79.8%	85.0%
Fcast Progress												

2015	Jan	Feb	Mar	Apr	May	Jun	Jul
IP Planned Progress							
Baseline Progress	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Actual Progress	91.0%	94.0%	97.0%	98.0%			
Fcast Progress				98.0%	99.0%	100.0	

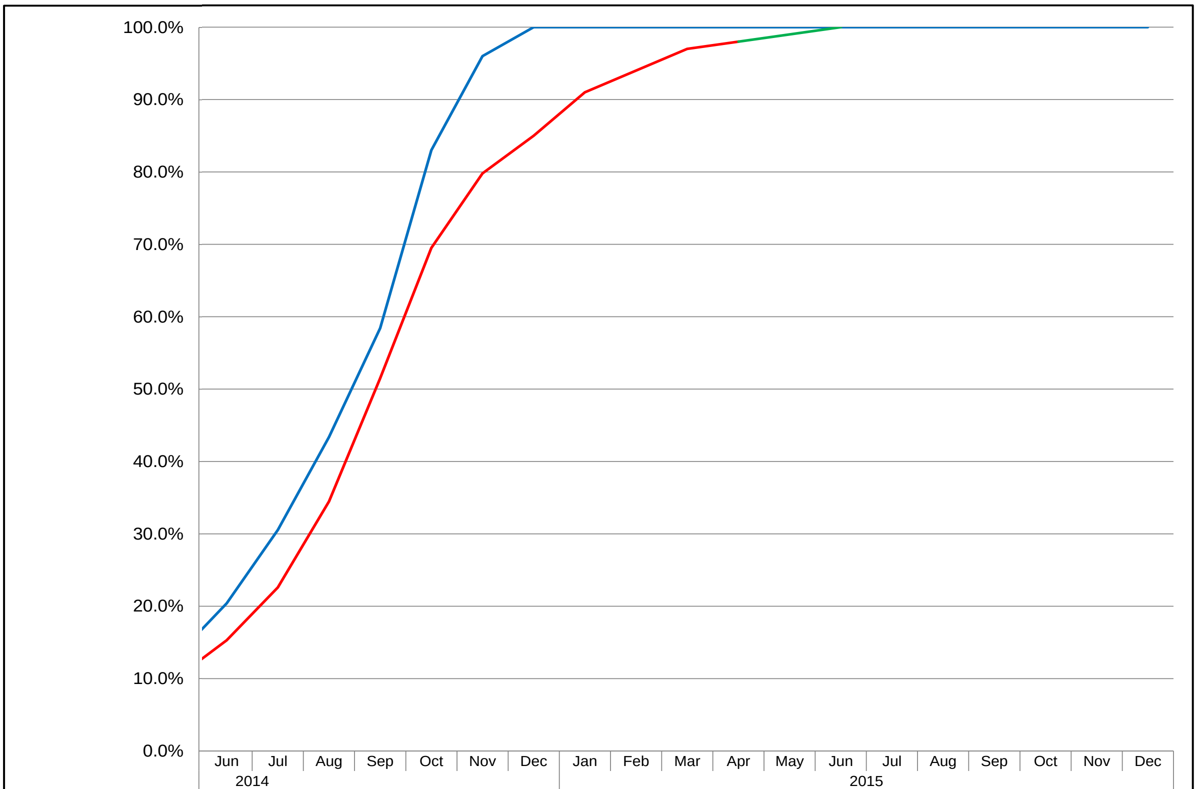
Figure 3-8: Global schedule for the WLDC construction and commissioning phases

As is evident from Figure 3-8, there is a clear deviation in actual progress from the planned baseline progress of the project that arises in January of 2014, a year after full project initiation. Once again, this deviation is more clearly illustrated in both Figure 3-9 and Figure 3-10 respectively. The underlying reason for the observed delay in schedule will be discussed in the following section.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
	2013												2014						
IP Planned Progress																			
Baseline Progress	0.0%	0.1%	0.1%	0.4%	1.0%	1.2%	1.6%	2.1%	2.4%	2.6%	2.7%	2.8%	3.0%	3.6%	5.1%	8.1%	13.0%	20.4%	30.5%
Actual Progress	0.0%	0.1%	0.1%	0.4%	1.0%	1.2%	1.6%	2.1%	2.4%	2.6%	2.7%	2.8%	2.8%	3.0%	4.0%	6.0%	10.0%	15.3%	22.6%
Fcast Progress																			

Figure 3-9: January 2013 – July 2014 schedule progress of WLDC



	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2014							2015											
IP Planned Progress																			
Baseline Progress	20.4%	30.5%	43.4%	58.4%	83.0%	96.0%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Actual Progress	15.3%	22.6%	34.5%	51.5%	69.5%	79.8%	85.0%	91.0%	94.0%	97.0%	98.0%								
Fcast Progress											98.0%	99.0%	100.0						

Figure 3-10: June 2014 – December 2015 schedule and forecast progress of WLDC

3.4.2 Project Delays: The Effect on Project Budget

There were few delays experienced on this specific project when compared to similar projects within both the construction and mining industry. Extension of Time (EOT) claims from contractors were due to the change in project completion date from the end of December 2014 to the end of March 2015. The factors that contributed to the above-mentioned schedule delay were as a result of the factors listed in Table 3-3.

Table 3-3: Project Delays and Causes on the WLDC

Description of Delay Cause	Impact of Delay
Rain during March 2014	3 weeks
Work stoppage by community pending allocation of work	1 week
NUMSA strike affecting column and roof steelwork erection	4 weeks
National Elections	3 days
Storm damage to facility	2 weeks
Local Contractors' absenteeism and turnaround of labour	3 weeks

When evaluated in conjunction with one another, Table 3-3, Figure 3-10 and Figure 3-9 provide an insight into the reasons behind the experienced global schedule delay. It is clear in Figure 3-9 that there is a deviation from the baseline schedule in March of 2014, a fact that is supported by the information on delays presented in Table 3-3. In this case it was a three week rain delay that was the cause of this specific delay. The effect of the further delays as listed in Table 3-3 are clearly visible in Figure 3-9.

The abovementioned delay on schedule would have been further exacerbated had it not been for the use of prefabricated columns (104 columns with a height of 10m each) instead of conventional in-situ columns as per the original design. This is a picture-perfect example of the use of complementary element construction (prefabrication) in a construction context to save time and money (see section 2.4.4). Complementary elements are pre-ordered and are constructed and fabricated off-site and delivered to site as needed, often employing Just-in-Time (JIT) principles. This type of production streamlining is ideal for use on uniform repetitive elements such as columns and this construction method in fact, provides a superior product to that of conventional on-site construction.

Another delay in schedule on this specific project that was avoided was the repositioning of the "store" and office block due to unforeseen soil conditions in the form of granitic bedrock. If this swift action had not been taken or if the design had not allowed for such changes the effect on project budget and schedule would have been catastrophic as blasting and extensive earthworks would have been required. The fact that the unforeseen soil conditions did not cause a significant delay was a mere coincidence and it should be noted that this was a result of extremely poor planning as this area is known to be geologically complex.

Further time-saving measures were implemented throughout the project in order to recover lost time, one of which was the use of an innovative flooring technique. The entire under-cover facility is host to a *Seamless FM2 concrete floor*, cast using state-of-the-art laser-guided concrete-flooring machines. This gargantuan task was completed in a mere three days, a task that would have taken a non-specialised contractor 3 weeks, if not more. The use of such specialised contractors to complete critical tasks was essential in the success of this project and avoided further possible catastrophic schedule delays.

3.4.3 Project Financials

Company A, who is the client in this case, after appointing the main contractor, insisted on the main contractor outsourcing every possible work package to community based companies. This inherently meant that the cost of construction would increase, a cost that *Company A* was willing to accept, for the sake of community upliftment and upskilling. This contributed to the majority of the cost overruns experienced on site.

This initial project tender took place in early 2012 after which the project execution incurred a twelve month delay due to both an Environmental Impact Assessment (EIA) and rezoning requirements (from agricultural land to Industrial) constraints. Both the rezoning and the EIA requirements were finalized and project execution began in January 2013. There was however a problem that arose due to this lag between tender and project initiation, the tender was no longer applicable due to price escalation, inflation and the escalation in cost of materials.

In January 2013, the forecast final cost of the project was increased due to the following factors:

- Project approval in August 2012 was based on designs at concept level of accuracy and not at an *FEL3* feasibility study phase deliverable.
- As a complete professional Engineering, Architect and Quantity Surveying team was not appointed, both the design and the Bills of Quantities (BOQ) were only at a concept phase level of accuracy.
- Prices were based on 2012 rates and prices.
- The market was not tested by means of going out on tender to determine indicative pricing.
- Input from the *Information Management (IM) Department* and *Protection Services* were not thoroughly consulted in building up the estimate.
- Allowance for Head Office Recovery (4.5%) and Owners Team management cost were not included in the estimate.
- Funding approval did not cater for escalation.

The above factors were assessed by the client and were taken into account in the formation of a new project estimate which was escalated at 16.8% from the initial R 119.7 million to R 139.97 million. The cost variance of R 20.212 million was as a result of the following cost drivers:

- A full Bill of Quantity (BOQ) was compiled from the final detailed engineering and architectural designs.
- 2013 Prices and rates were utilized based on the construction industry materials and equipment prices.
- The market was tested by going out on tender and the tendered price was used as a benchmark. This included for escalation allowance for 2014.

- Detailed *IM* and *Protection Services* prices were submitted and formed part of the whole project estimate.

By pro-active value engineering and scope management the cost increase has been mitigated down to R 20.2 million whilst not compromising the project deliverables. The additional funding requirements and areas of allocation are as detailed below:

• Owners Team	R 2.5 million
• Head Office recovery	R 5.8 million
• IM and Protection Services	R 4.7 million
• Escalation and updated BOQ	R 5.5 million
• Contingency restatement	R 1.7 million
Total	**R 20.2 million**

Once the project was in the execution phase further cost increases were as a result of the following circumstances:

- Increase in Architectural fees due to the relocation of the outside stores as a result of rock outcrops encountered. This is in essence rework.
- Additional project management cost from the Protection Services Department due to outsourcing of this activity as they did not have sufficient internal capacity.
- Additional fencing costs due to extending the site footprint area to within the allowable approved EIA area to allow for future capacity expansion requirements.
- Upskilling and training costs due the appointment of local contractors that was not allowed for in the original budget estimate,
- Severe storm damage on the warehouse sheeting during November 2014 that resulted in rework and knock-on access delays for other contractors.

During April 2015, the budget was reviewed and assessment of the above factors resulted in a final project estimate which was escalated by 2.76% from the previous approved budget of **R 139.97 million** that is comprised of direct and indirect costs as outlined in Figure 3-11 and Figure 3-12 respectively.

This budget was amended to **R 144.44 million** as per the breakdown indicated in Figure 3-13. The variance of **R 4.47 million** was as a result of the below-mentioned cost drivers:

• Architectural costs	R 1 100 110
• Fencing quantities	R 120 085
• Protection Services	R 427 726
• EOT Claims	R 603 000
• Local community procurement / training	R 1 149 426
• Plastic Bins & Labels (Add Scope)	R 460 220
• Rack Grouting & Signs)	R 473 251
• Head Office 4.5% fee recovery	R 138 128
Total	**R 4 471 946**

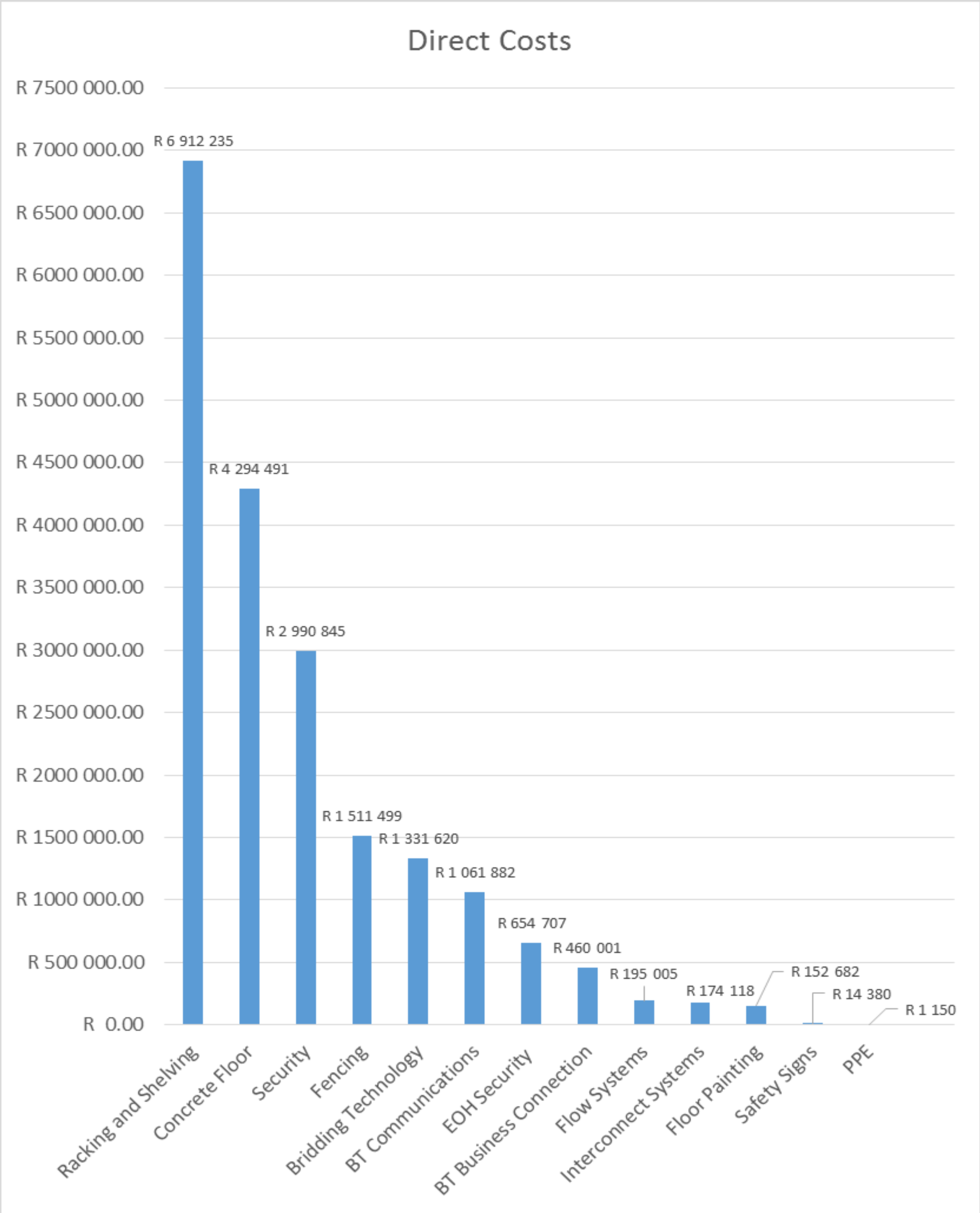


Figure 3-11: Summary of direct costs for the WLDC project

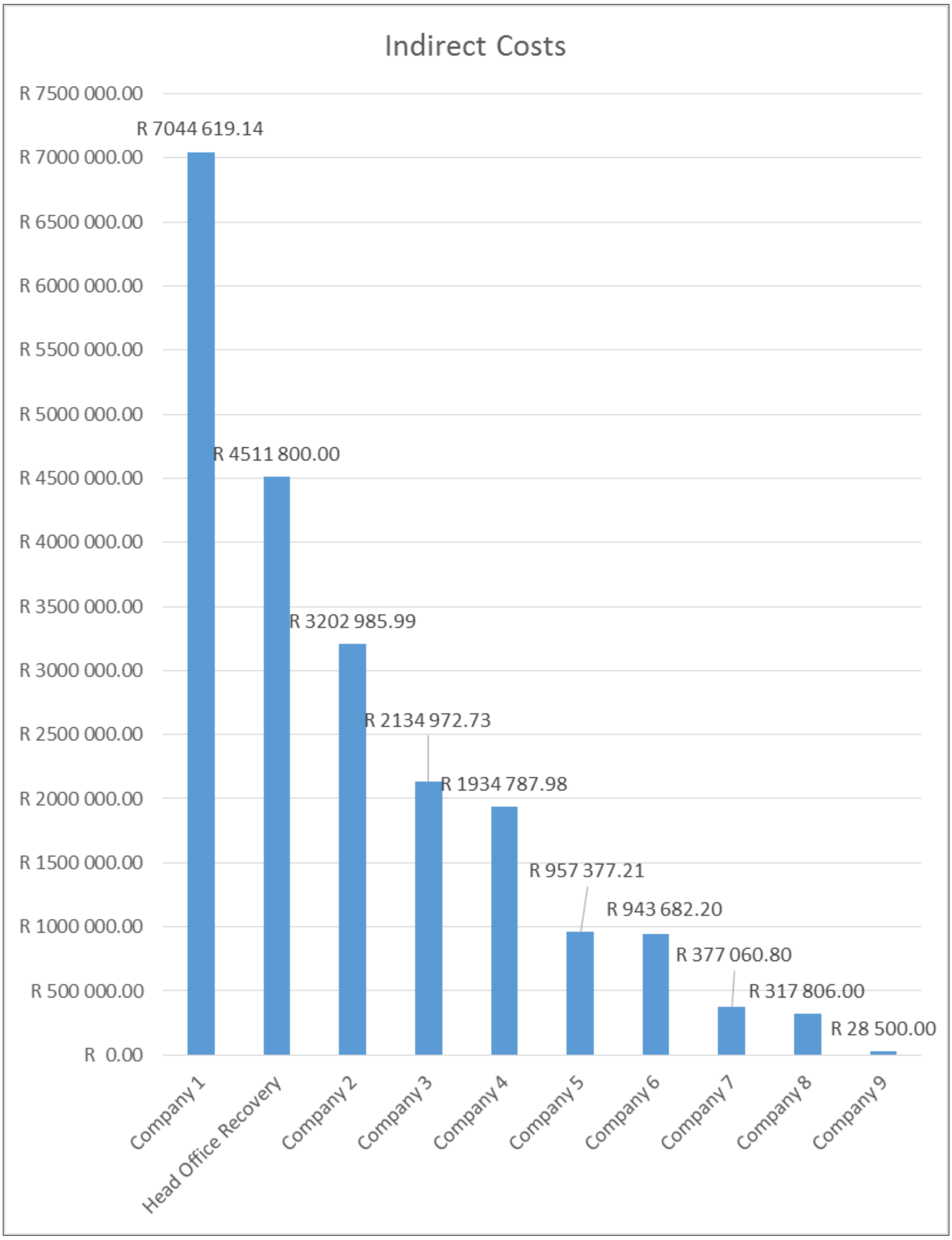


Figure 3-12: Summary of indirect costs for the WLDC Project

It should be noted that Figure 3-11 does not include the tendered amount payable to the main contractor of **R 100 million**. As can be expected from a warehouse type project, a large amount of the direct cost was attributed to racking and shelving, an amount of almost **R 7 million**.

Further, the amounts presented in Figure 3-11 can be considered industry standard since there exists no abnormalities in this section. The amounts presented in Figure 3-12 will not be discussed further since permission from suppliers and consultants was not granted in this regard. For the sake of confidentiality, the names of such companies are concealed.

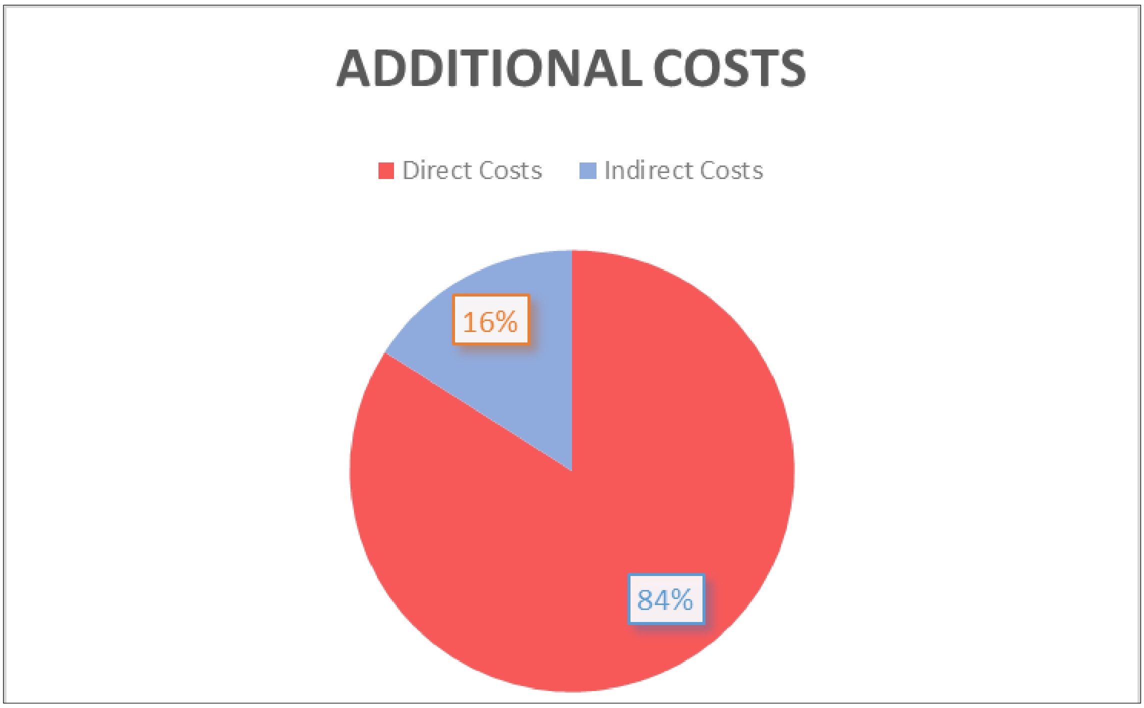


Figure 3-13: Additional costs breakdown for WLDC budget

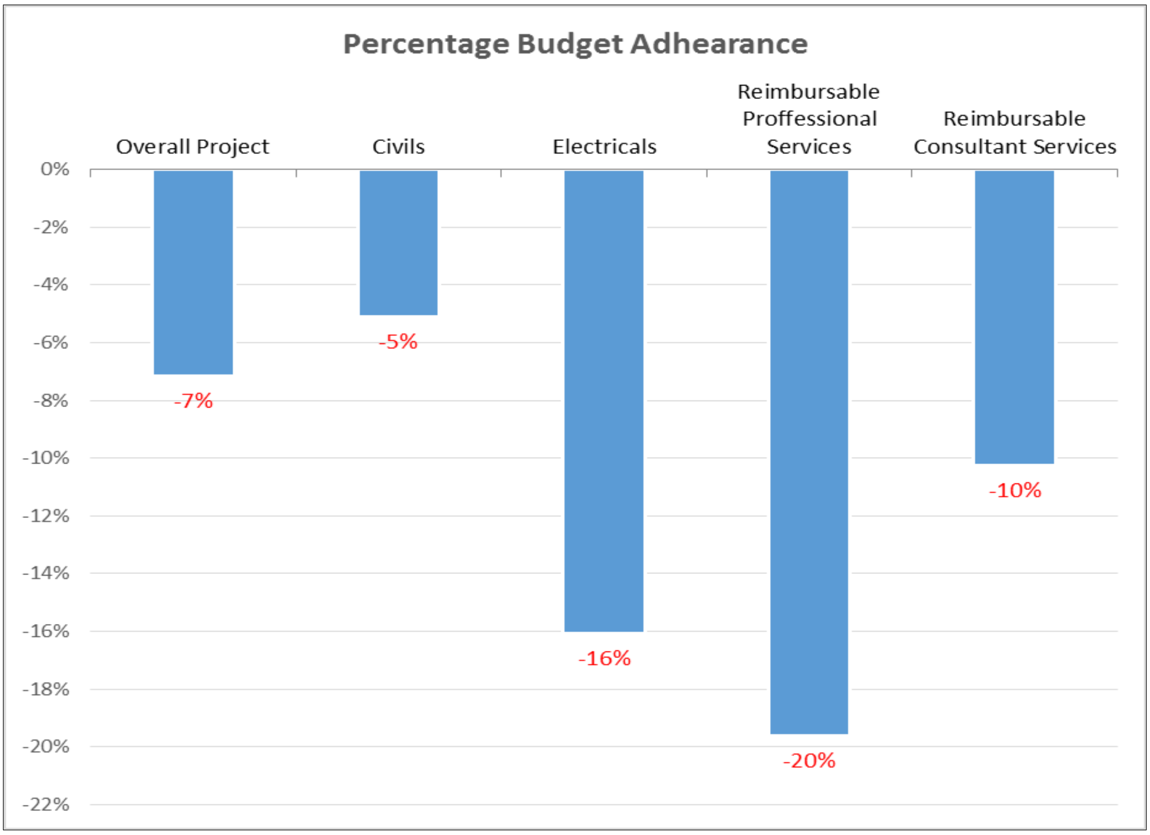


Figure 3-14: Budget overrun on WLDC project as percentage

The budget overruns are due to the factors discussed earlier in this section and are essentially a result of poor quality work on the part of local contractors coupled with inadequate supervision. A summary of the budget overruns are as presented in Figure 3-14. It should, however, be noted that this overrun as a percentage could be misleading. As such, the overrun as a monetary value is presented in Figure 3-15.

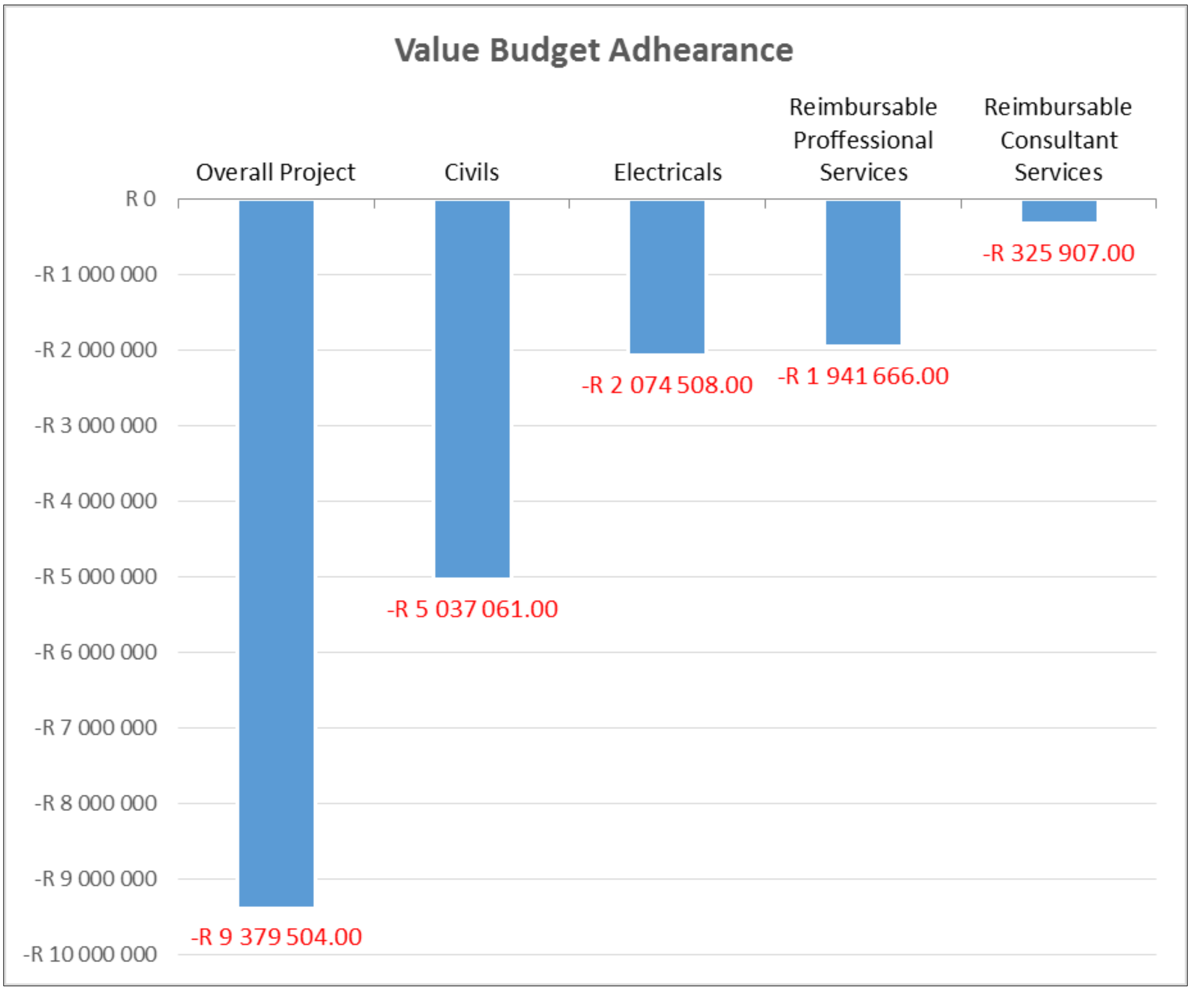


Figure 3-15: Budget overrun value for WLDC

From the values presented in Figure 3-15 and the percentage overrun shown in Figure 3-14, the most critical budget overruns were encountered in the electrical and civils section of the contract. This agrees with the evidence presented earlier, suggesting that a combination of inadequate supervision and inexperienced contractors and subcontractors were the main reasons for the experienced project delays.

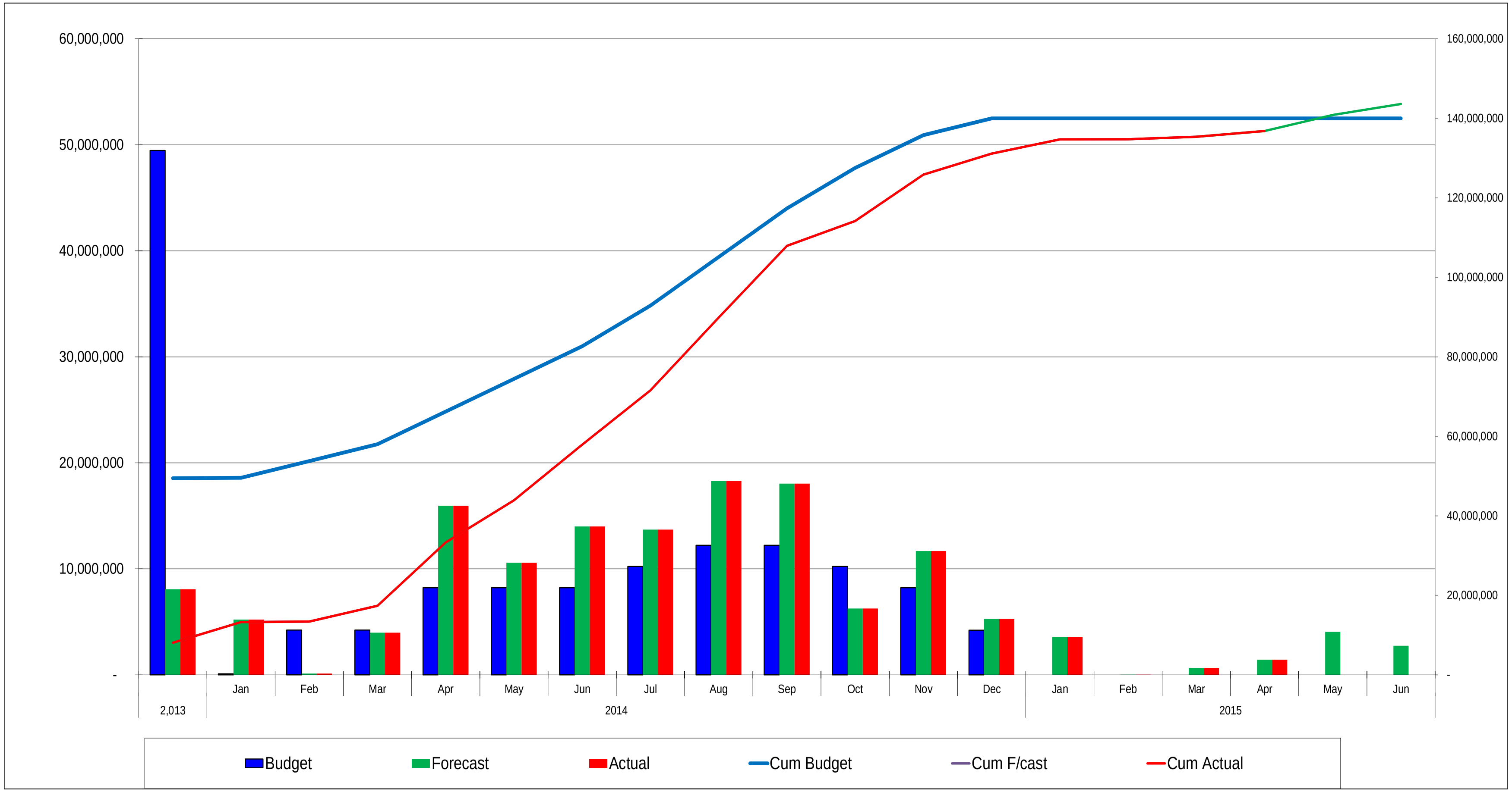


Figure 3-16: Financial Progress of the WLDC project

Chapter 4. Results and Findings

The findings presented in this chapter are based on information gathered through interviews, direct observations, interpretive data and discussions whilst conducting a case study at the WLDC project.

4.1 BEE: The Effect on Project Execution

As discussed in sections 2.3.1 and 2.4.5, there exists a unique dynamic within the South African economy. BEE and BBBEE are both government driven initiatives that form part of an economic empowerment program. The goal being to redistribute wealth throughout previously disadvantaged South African societies in an attempt to rectify the inequality brought on by apartheid. This has placed pressure on big businesses, especially large corporate companies, to invest in black owned companies where possible.

The mining sector has been placed in a rather precarious position by government and militant local communities. Government and local business forums insist on support of local businesses, regardless of their training or skills in all endeavours or capital expansions within the area. As the mining industry is a highly specialised field, it often requires the services of specialised, consultants and requires less unskilled personnel. This highlights a significant challenge for the mining sector as a whole, a balance between specialised and local contractors needs to be found. *Company A* is one of the mining industry's leaders when it comes to community upliftment and skills development and have extensive programs in place in order to comply and further BBBEE initiatives.

With reference to the specific project under review, the WLDC, there is a complex BBBEE component that needs to be evaluated. With this specific project, as is the case with the majority of projects in the mining sector and projects initiated by *Company A*, the socio-economic and political narrative has the potential to play a pivotal role in the success or failure of the project. For the project under review, there was a dedicated business forum through which all community projects and local contract opportunities will be evaluated and processed. Below is a summary of the commitment by *Company A* to furthering general community upliftment initiatives in the area:

- A community business forum will meet on a bi-weekly basis to discuss community development.
- There will exist a BOQ for ring-fenced opportunities and work packages.
- A steering forum will look at partnering on specialized packages, as well as bulk earthworks, steelwork, sheeting and electrical scope of the project.
- The business forum will identify on-going opportunities for job creation after project completion (I.e. cleaning, garden services, security etc.)
- The business forum will supply a shortlist of potential partnering companies from which, *Company A* will appoint the most suited and qualified company.

- The business forum will implement skills transfer opportunities and initiatives throughout the project.

Through negotiations with community leaders, the business forum and stakeholders from *Company A*, a number of substantial contracts were awarded to local contractors as outlined in Table 4-1.

Table 4-1: Summary of work allocated to local contractors

Description of work package	Approximate tender value	Quantity of work	Local company
Bricklaying and Paving	R 3.10 m	6042 m^2	*KRR&K / O&M*
Internal Fencing	R 53 k	50 m	*Magasa*
Carpentry (Doors, Ceilings, Partitions)	R 408 k	480 m^2	*Seruti*
Interior plastering	R 859 k	8140 m^2	*Zizanani*
Tiling (Floors and Walls)	R 1.78 m	4100 m^2	*O&M*
Plumbing for buildings	R 1.04 m	68 no	*T&R*
Painting	R 323 k	11248 m^2	*T&P*
External Works (Kerbing, Sleeve pipes, Manholes, Catch Pits)	R 3.77 m	n/a	*Vidiza*
TOTAL	**R 11.33m**		

This amount of R 11.33 million equates to roughly 8.7% of the project value. Historically Disadvantaged South Africans (HDSA's) received payments totalling R 3.69 million from this relatively small project (for the mining sector). This is as a result of pressure from new government legislature requiring that mining companies have a minimum of 26% ownership of HDSA's by the end of 2014 in addition to the requirement that a substantial portion of procurement by mining companies is from black owned companies.

The penalties for non-compliance on the part of a mining company places their right- to-mine at risk, a risk no company is willing to take due to the catastrophic loss of income that would occur from such a situation. As a result, mining houses have no choice but to support HDSA owned businesses regardless of their credentials or competency rating (Smith, 2014), not based on merit, experience or competitive advantage but rather on political policies.

The allocation of work to HDSA's and Black-Owned small and medium enterprises is by no means a bad thing, in fact it is an essential part of redressing the inequalities of the past. However, the manner in which these HDSA companies are managed is the point of concern. Regardless of the work package, companies such as *Company A* who have such vast experience working with such companies and any other company for that matter, know that there is an onus on the owner, the client, to implement effective management practices. This is essential in the mining field specifically, as it protects the main interest of the client, mining. An activity that could potentially delay mining activities is an extremely critical activity and needs to be managed as such. If for instance, a task of constructing a retaining wall is being executed by a contractor, this wall is essential to the furthering of mining activities on a specific shaft that, for arguments sake, produces R 5 million rand a day. If the task of constructing the retaining wall has been scheduled over 4 days, the duration of a scheduled mining shutdown on the specific shaft, then this is the absolute maximum time that is allowable for the wall construction. Essentially every day that the wall construction takes over and above the scheduled 4 days is money lost for the mine, lost opportunity. It is clear that this task needs to be meticulously planned and managed in order to prevent a loss of R 5 million per day. Thus, any contractor requires management by the client or client representative in some shape or form, the degree to which this management is implemented may vary from project-to-project and task-to-task but there is no questioning the necessity of control and management, especially on critical tasks. However, when an inexperienced contractor is involved with a critical task, the degree of management that needs to be enforced by the client needs to be re-evaluated. Due to the lack of experience and often skills, HDSA contractors need to be systematically managed to ensure that the work or service they are providing is of an acceptable standard and is being timeously executed.

Companies such as *Company A,* are expected to uplift such contractors by means of skills transfer, thus in this context, systematic management does not necessarily mean micro-management. Systematic management implies that there should be policies in place to facilitate the necessary skills transfer that inherently takes longer than simply “completing the job”. This is a reality in South Africa, skills transfer and pressure to support sub-optimal suppliers and contractors is something that shows no sign of changing (Benjamin, 2014). It is thus imperative that companies that expect to prosper in the South African construction industry cater for these intricacies of doing business, for the sake of furthering skills development initiatives and for the benefit of the country as a whole.

4.2 Project Specific Complexities

As mentioned in sections 3.3.1, 3.4.2 and 4.1, each project, especially in the construction industry, will be unique in some way. This forms the foundation from which one of the strongest oppositions to an SCM approach to management of a project is founded. Many of the industry role-players involved with the WLDC project expressed their concern with regards to a management approach similar to that found in manufacturing.

The reasons behind this concern differed from interviewee to interviewee with the underlying concern in essence being that a “project” or product in the manufacturing industry is not unique. Role-players advocated that the each project in the construction industry involves the construction or development of an entirely unique product, in contrast to the manufacturing industry where a single product is repeatedly manufactured. As well as this so called “product- uniqueness”, the other major concern that was highlighted in the feedback from industry was that product development in the manufacturing industry takes place in a highly controlled environment whereas in the construction industry, each project is infinitely unique and the environment uncontrollable.

The complexity that exists in projects has different meanings in different organizations and thus if a companies’ leadership feels that the work is complex, it should operate in a manner that will negate the effect of complexity. How a company anticipates, understands and navigates complexity determines the success of both an organisation and specific project.

It is important to acknowledge that complexity is not something that is going to go away but rather it will only increase, effective management of complexity will result in competitive advantage, especially in the construction industry. Due to the large budgets that are common course in construction projects, successful management and mitigation of complexities can potentially save organisations billions of rands.

To focus on this so-called project complexity and peculiarity that exists in the construction industry, a summary and discussion of the project-specific complexities and peculiarities encountered in the execution of the WLDC project is presented in Table 4-2.

Construction companies, EPCM’s and consultants need to establish their mission statement and outcomes in a manner that is easily understood by all stakeholders involved with a specific project while being direct and specific enough to adequately reduce complexity and by doing so, reduce risk. Successfully managing risk on a project is an important issue that faces industry and thus reducing risk through effective management of complexity can serve to reduce and quantify risk more easily.

Table 4-2: Identified peculiarities specific to the WLDC project

Identified Project Complexity	Description
Industrial Action (Strikes)	Strike action over unresolved social or financial disputes, often violent
Local Contractor Performance	Inexperienced contractors producing substandard work
Noncompliance to safety standards	Inexperienced contractors failing to follow mining safety regulations
Extreme Weather Conditions	Abnormal weather condition (Rain and Wind)
Local Community Forums	Political unrest and disputes as a result of social issues, employment and wages
Upskilling of Contractors	Having to train appointed contractors to complete the work they tendered for, at the clients cost
Lack of Experienced Supervision	Contractors failed to appoint experienced personnel in critical managerial positions

Table 4-3 is an outline of complexity, according to *Snowden* and *Boone*, this is a framework that companies such as *Company A* can implement as a reference when evaluating project complexity. Based on the degree of complexity of the project, risk mitigation measures can be out in place and complexity can be navigated and reduced through established engineering and management practices. Project Management does not allow for adequate leadership and decision making when confronted with projects of high complexity and managers thus require a tool that is able to enable managers to understand advanced technologies, global markets and cultural diversity while acting against their intuition and experience.

The WLDC project is by no means a complex, world first project. The project entails satisfying the exact same critical success factors as those outlined in Table 2-10. A distribution centre is essentially a simple combination of a large warehouse structure and an inventory management and processing system. The degree of complexity of this project is “*Simple*” yet the management of this specific project proved to be challenging.

Table 4-3: Project complexity grading (Snowden & Boone, 2007)

Degree of complexity	Characteristics of Complexity
Simple	• Repeating patterns and consistent events • Clear cause-and-effect relationships evident to everyone where a right answer exists • Known knowns • Fact based management
Complicated	• Expert Diagnosis required • Cause-and-effect relationships discoverable but not immediately apparent to everyone; more than one right answer possible • Known unknowns • Fact-based management
Complex	• Unpredictability • No right answers; emergent educational patterns • Unknown unknowns • Many competing ideas • A need for creative and innovative approaches and alternatives • Pattern-based leadership
Chaotic	• High turbulence • No clear cause-and-effect relationship, there is no point in looking for correct answers • Unascertainable unknowns • Many decisions to make and no time to think • High tension • Pattern-leadership

This was primarily due to the fact that *Company A* was under pressure from both government and local community business forums to outsource the vast majority of work to local contractors and to source the bulk of the materials from local companies. However, the local contractors were a collection of unskilled individuals rather than an organised company. These companies often comprised of labourers without any knowledge of the business world and no experience in business administration. This proved a major challenge to the project team, in turn increasing the complexity of the project to "*Complex*".

There suddenly emerged a completely different degree of complexity to the otherwise straightforward project that created a need for innovative and creative approaches to solving problems. There was a certain degree of uncertainty with regard to the quality of work produced by the local contractors as most of them had little or no experience and needed to be trained and upskilled by *Company A* before being competent to complete the job at hand.

4.3 Summary of Findings

A combination of poor on-site supervision and inexperienced contractors (mainly subcontractors) can be criticised for being the greatest challenges of this project. The effect of this lack of supervision as well is especially evident with regards to minor work packages such as painting, tiling and bricklaying, the quality of which is far below the industry standard. Although many of these tasks were not on the critical path of the project, delays resulted in lost time and created a degree of frustration with the management team and other contractors who were in turn delayed. Time extensions were applied for by the majority of the contractors, however, the correct procedures were not followed and this resulted in claims being protracted and in some cases, denied. According to an interview with a senior manager on site, “when local contractors are involved in such a project, as is the case on this specific project, there should be at least a 10% allowance in budget and schedule to allow for effective learning and skills transfer”.

In this project there was limited effort made to involve subject experts during the feasibility phase. Such a consultation would have ensured that a “community specialist” was consulted regarding the enforcement of BBBEE and community upliftment and procurement. Local contractors should have been accounted for, for training purposes when or before tendering processes are initiated, this will allow for a more effective skills development process. An enhanced skill development process will result in a more professional service on the part of the contractors. This will be to the benefit of the contractors, subcontractors and ultimately to the client, *Company A*.

The successful implementation of the abovementioned skills development strategy lies in the degree to which the project is planned. Appropriate planning is a critical success factor for any project, especially when dealing with intricacies such as those encountered in the WLDC project and many other projects within South Africa. Many of the issues associated with the WLDC project can be blamed on inappropriate planning on the part of *Company A*.

It was found that there was not a dedicated project planner or scheduler appointed on this project by either the main contractor or the client. As a result of the lack of experience in planning and scheduling, there was no resourced schedule for this project. This implies that the capacity of available resources was not considered to be important, rather a traditional approach to management was adopted, the so-called “given date” approach. A given date, when calculated, does not explicitly evaluate both the timeframe and the availability of resources that often leads to unrealistic targets and expectations. A TOC type approach would have been more suitable for tasks that are directly dependent on resource capacity, adopting a forward pass type approach to scheduling. A forward pass implies that a task once completed, will pass on the “product” to the next resource to complete their task.

The scheduling method used in the WLDC does not lend itself to such management of tasks, rather, a schedule as per TOC could possibly prove more effective in such a project, where there exits close supervision on the part of the client and a lack of management experience on the part of the contractor.

The vast majority of the delays and associated cost implications thereof are a result of poor performance on the part of contractors working under the main contractor as subcontractors. This was, at the time of tender, not a concern for the main contractor, who is now held partially liable for the delays and incurred costs. This change in employment strategy was due to political pressure from both government and *Company A* to employ and outsource work to local communities. Once the tender was accepted, the main contractor was obliged to outsource a certain amount of work to HDSA-owned companies and black-owned companies. This pressure to use certain companies based on their geographic location and ownership demographic created a degree of frustration amongst professionals such as experienced contractors and managers on site who know that there are contractors that, for the same money, will produce superior quality work in a shorter time and will require less supervision in order to do so.

That does not absolve the main contractor from their failure to adequately implement the necessary supervision and management of the subcontractors in question. There is no doubt, based on the evidence gathered through interviews, that the main contractor did not provide adequate supervision of these subcontractors which in turn lead to poor quality work, mistakes, rework and additional expenses.

If it was not for the pro-active value engineering, scope management, contractual penalties of R 10 million and innovative time saving measures employed in the project, delays and the effect thereof would have been catastrophic and this project would have joined the extremely long list of "behind-schedule and over-budget" projects in the construction industry. Instead, this is considered, by a number of interviewees as being one of *Company A*'s most successful project executions, despite being over budget by almost R 5 million. This amounts to only 3.2% budget overrun.

However, the project completion date was delayed by more than six months, the value of which is challenging to quantify without divulging extremely sensitive and confidential operational information pertaining to *Company A*. For this reason, no such attempt will be made, although the lost opportunity costs of a six month delay must be significant and the ramifications of knock-on-delays substantial.

Company standards also create extra cost and result is delays, it's self-inflicted to a point. For instance, each and every contractor on site requires a certain background check, health check-up, etc. This is necessary but the degree to which it is implemented and the details that *Company A* requires is, at times, an extreme hindrance to progress as certain personnel take weeks going through the various processes required for them to be able to work on a certain site or in certain conditions. This creates delays and staggers the progress and flow of work. Another example of company policy being a challenge in the case of this projects is the need for specialised training for certain jobs. For instance, to work at heights, one needs a certain qualification, the law may stipulate that "at heights" is anything above two meters off the ground, however, *Company A* will instead create their own standard of, "at heights" is anything over one meter above ground.

This is purely an internal requirement and may not be necessary. The "working at heights" example is a simple one but internal company policy is often a serious hindrance to progress and should be revised to ensure work on such a project is both safe and efficient.

Instances of supply chain management implementation

This specific project made use of no Supply Chain Management (SCM) techniques or theory except for a very limited used of prefabrication and continuous construction.

Prefabrication, more formally known is complementary element construction was implemented in the construction of the warehouse structure itself. The steel roof structure is supported by 104 reinforced concrete columns each ten metres tall. The construction of such an element requires many components, including formwork erection, concrete mix design, vibration, and reinforcement placement and curing. The controlled environment such as that in an off-site factory lends itself to such repetitive construction. In such a facility, the process can be optimised and the entire supply chain integrated to allow for seamless construction (assembly) of the elements.

This is no different to mass production where the same product is produced over and over. It is a well-known fact that such an operation can be meticulously optimised to operate at peak capacity while maintaining a superior quality product to one that is produced in a systematic fashion.

Based on interviews and discussions with key management personnel, the names of whom will not be mentioned for the sake of confidentiality, claimed that the use of such elements saved the project in excess of 4 months schedule as opposed to if conventional construction methods has to be used. The elements, according to interviewees, were of a far superior quality to those produced on-site and the elements that were defected were returned to the supplier at no cost to the contractor. This transferral of risk from the contractor to the supplier is synonymous with the retail industry and is in-line with the concepts of SCM.

"The cost of such a complementary element approach was at least 30% cheaper than conventional in-situ construction" according to an interviewee, who further acknowledged the tremendous time saving as a result of prefabrication, not to mention the superior quality and finish of the individual elements. Complementary element construction provides a far safer working environment for workers who are involved with the process and since the mining industry places significant value on safety, complementary construction should be used wherever possible to limit the risk to on-site construction personnel (PWC, 2013; Quayle, 2006).

Based on the evidence provided above, it is hard to deny the vast potential for cost and time savings that lies in the used of prefabrication, especially for the construction of complex or repetitive elements. There is no doubt that in general the quality of such elements is far superior that that of in-situ constructed elements. Another benefit of using prefabrication in the construction industry lies in the potential to create permanent jobs, jobs that afford workers a high level of training and up-skilling, a major concern for both government and employers such as *Company A*.

There is no rationale in literature that argues against the fact that prefabrication construction methods and the associated industry thereof, provides permanent jobs as well as a high level of skill to employees, who in turn earn greater salaries than conventional construction workers (Ofori et al., 1996; MacKerron, Kumar, Benedikt & Kumar, 2014; Doloi et al., 2012; PWC, 2013). This is especially true in the South African context, where there exists a need to create permanent employment opportunities rather than short term employment.

Chapter 5. Discussion

A discussion of the findings of the study in relation to theory introduced in the literature review will serve to prove or disprove the validity of a possible SCM approach to managing construction projects. The discussion of the findings of the case study make direct reference to data, both qualitative and quantitative, that was gathered from the WLDC project as well as both formal and informal discussions with key industry role-players. In some cases, new literature may be introduced in order to supplement the qualitative research findings that are presented in this Chapter. This chapter will likewise address the practical implications of the research. Success factors of projects as well as the requirements for achieving project success are discussed along with a philosophical but scientific review of the future of management.

5.1 Project Success Factors

The following are considerations, based on the findings of *Chapters 3* and *4*, that may be applicable to projects with similar complexities which may be executed in the future. Such challenges are commonly encountered in South African construction projects and as such, should be thoroughly discussed and considered when evaluating alternative approaches to conventional project management processes and methodologies.

Project success factors are discussed in relation to specific contracting models and common project management challenges. This section serves to present a recommendation as to broad-spectrum-management best practice implementation. Furthermore, the requirements of project success are delineated and recommendations made with regards to the process of achieving success in construction projects.

Upskilling and training programmes

The learning and skills transfer programme should be treated as a business instead of a community engagement project, there should exist clearly defined plans with regards to the processes that are to be implemented and a detailed budget outlined to fund this process. This endeavour should ideally be run as an entirely autonomous operation, separate from *Company A's* project management team. This separation and delineation of responsibility will provide a degree of accountability on the part of training providers and will serve as a formalised learning process. Being able to hold a "third party" accountable for a lack of skill or technical knowledge will benefit *Company A*, as they will be able to reduce their operational risk. Furthermore, this training facility and service can be a community project and could provide necessary skills and jobs for HDSA's.

If this process is implemented as an external "business", once project pre-feasibility studies are initiated and the project is given the go-ahead, the process of skills transfer and training can commence. The earlier this process is started, the less time that will be wasted during project execution, where time is money - a limited resource. This will lower the project complexity significantly from as early as the project planning phase.

The benefits of this process would be two-fold. On the one hand, once certain skills are required to successfully complete a certain site activity, the persons performing the work will already possess the necessary skill-set required for successfully implementing the work at hand. This will save valuable time and will limit knock-on-delays. The second benefit will come in the form of improved quality of work and will result in improved personnel efficiency once on site. This translates into fewer persons on site, limiting the risk of on-site-injuries.

A further benefit exists in the fact that once an individual has completed the relevant skills training, they will possess the necessary accountability required to successfully execute the work at hand, in a professional manner. This process of training will also serve as a grading process, where personnel can be graded according to abilities, skill-levels and specialities. This will ensure that the correct individuals are placed in the correct job roles, according to both ability and personal affinities and personality. The potential that exists in this concept is significant. If a labourer is in a job role that they truly enjoy, their productivity and wellbeing will improve and in turn this will result in a content worker, someone who is proud of their position and the company for which they work.

Schedulers and planners

Successful planning needs to be seen as a profession, as is the case with engineering, planning needs to be conducted by dedicated personnel. It is the opinion of the majority of interviewed managers that the many of the problems that arise on site are a direct result of poor and inadequate planning or in some cases a lack of planning all together.

The need for qualified schedulers is another point that needs to be addressed in order to improve the project management of projects. Many schedule and as a result, budget issues, are a direct result of poor scheduling. It is extremely uncommon to find a resource-loaded-schedule in construction projects. Those that do exist are often rudimentary attempts at resource-loaded-schedules and are developed using little or no scientific or management skill. There is no use in having a resource-loaded-schedule if it is based on poor calculations. As suggested earlier, this task needs to be conducted by a qualified, skilled scheduler in order to add value to the management of a project.

The importance of effective planning cannot be understated, employers such as *Company A* need to employ planners and schedulers as critical staff and need to make such jobs well paid positions as the potential savings that could be realised by effective planning and scheduling have the potential to be significant and could possibly exceed the cost of employing the best possible planners.

Effective management and supervision

Planning in the mining industry is traditionally something that is given little attention according to three senior management personnel interviewed at *Company A*. As is the case in manufacturing, extensive planning is key to successful project execution. Planning limits the need for a “fire-fighting” reactive management strategy, according to an interview with the head of asset management at *Company A* as well as a senior manager of one of *Company A’s* largest divisions.

Through effective planning at the earliest possible stages of a project, plans can be put in place to ensure the provision of effective management and on-site supervision. This was one of the main contributing factors to the poor quality workmanship that was encountered on this specific project. Absenteeism on the part of subcontractors and their labourers proved also to be a significant issue on this project, this can only be solved through the implementation of effective management techniques. This is the responsibility of the main contractor and their subcontractors, however, since *Company A* stands to lose significant amounts of revenue in the case of a delay, it is imperative that there are dedicated management teams in place to oversee the management of the main contractor and their subcontractors. This is not intended to be a micro-management exercise but rather a facilitation role, to oversee the successful management of critical on-site tasks and issues.

Corporate responsibility

It is no secret that the South African economy is suffering tremendously due to the reluctance of large corporates to invest in the country as a result of an unstable economy and due to political issues. Among the many challenges that face companies, especially in the mining industry, is the fact that local municipalities tend to use these corporate companies as solutions to their own problems. It has become expected that if a company such as *Company A* is intending on mining in a certain area that they provide schools, hospitals, transportation and water reticulation to name a few. This is in fact not the legal responsibility of the mining company but rather local municipalities', these are factors that only add to the image of an unfriendly investment opportunity. This is an issue that needs to be looked at by government in order to make investing in such endeavours more appealing. However, *Company A* feels that the onus to upskill and uplift people lies with the corporates that operate within South Africa, it is the correct thing to do from a social standpoint and it will help resolve poverty and uplift people in the area of operations of company in question. This will be beneficial both to the company and to the local communities. *Company A* is achieving this through various community projects, the construction of the abovementioned infrastructure and create small and medium sized enterprises via the use of Joint Ventures (JV's). This is however, not the legal responsibility of corporate companies but rather their social commitment to developing the communities in which they operate that drive such initiatives.

Business administration

The vast majority of contractors and small business owners understand the technical side of their trade or service but often lack business management and administration skills (Ahadzie, Proverbs & Sarkodie-Poku, 2014; Attarzadeh & Ow, 2008). This is true for both established and new businesses. As such, *Company A* is working on a skills upliftment program to train and upskill locals and HDSA's and business owners. The majority of the problems associated with poor business administration are in quoting and tendering skills. The failure of business owners to effectively tender results in either penalties from the client or a significant loss of revenue for the company in question.

The program needs to be an external program that will facilitate skills upliftment to transfer non-technical skills such as business administration, basic business management and financial literacy. This should be paid for by *Company A* as it will, in the long-run, benefit them as the client, as contractors will be able to tender more effectively, resulting in more accurate budget and schedule designs.

Such business skills will enable such companies to become self-sufficient and competitive in the broader SA. Not only dependent on companies such as *Company A* that are obliged to support them, but competitive based on some sort of competitive advantage or skill-set. Currently many major suppliers are obliged to work hand in hand with locals in a JV manner to create local companies. The value to South Africa and to *Company A* lies in the formation of small and medium sized enterprises not in coalitions such as JV partnership agreements.

Critical Chain Project Management

Certain aspects of project management are not acknowledged by PMBOK project management, as such, aspects such as the effects of BBBEE, skills development and political and economic pressures are deemed to be un-controllable. Such intangible measures could be managed by means of Theory of Constraints (TOC), more specifically, Critical Chain Project Management (CCPM).

CCPM involves the implementation of a "critical project time buffer". The idea of time buffering is not unique to TOC, PMBOK activities and schedules also account for time, resource and cost buffers, however, the manner in which such buffers are defined and managed differs considerably.

Conventional PMBOK management strategies such as Critical Path Project management (CPPM) incorporate all the above-mentioned buffers. However, instead of allocating each and every task on the critical path or the entire project for that matter, the CCPM approach ensures that the overall project deadline is protected by buffers, not each and every individual activity in the project. If, for instance, each and every estimate of time, resources and cost was to account for the risk of unstable economic conditions, unrealistic BBBEE procurement and employment requirements, strikes and labour-union action, the overall cost, schedule and resource requirement estimation for the overall project would be significantly over exaggerated.

The sum of each individual task buffer would translate into significant increases in the overall project time and more importantly, the budget of the project as a whole. As such, it is recommended that when such project constraints exist, a *Critical Chain* approach to management should be used instead of conventional critical path management.

The critical time buffer that is used in the CCPM approach of TOC is the best way in which intangible political and socio-economic pressures that effect project management can be managed. Such issues cannot be changed nor can they be accurately predicted, others are law. The CCPM approach involves implementation of a critical time buffer that comprises of political time, strike time, incompetence time etc. This is not taken into account in the SCOR or BSCOR model, further affirming the point that there exists no single management approach that satisfies each and every project.

5.2 Project Success

What is required for projects, such as the WLDC project and that discussed in section 4.1, what is the missing ingredient in the South African construction industry? According to a leading industry expert (see *Appendix B*, *Respondent 4*), a constituent of successful project execution is effective planning. Since no two projects are identical, each and every specific detail needs to be methodically planned, from procurement, to installation, to handover and commissioning, to the point where the planning of a critical task is itself planned. Planning can be in the form of planning merely by experience and intuition, planning by the application of fixed systems or planning by individual design of the main process and organisation according to project specific characteristics and challenges. When planning one needs to evaluate if there are many or few project parameters

Another important constituent of successful project execution is communication (Makris et al., 2011), without effective means of communication, no project has the potential to be managed correctly. Effective communication further stimulates collaboration amongst project stakeholders which is an important challenge to overcome in an industry as fragmented as construction.

5.2.1 The State of Construction in the Eyes of Project Managers and Project Engineers

The data presented in this section is based on qualitative data obtained through a series of eight informal interviews/discussions and observations, the summary of which is as follows:

Project Management practice

There exists a need in construction projects for integrated project management systems. The size and degree of complexity that exists in modern construction projects requires coordination and control in order to keep key stakeholders informed of schedule and cost performance. Systems such as BIM are great for allowing fast decision-making and coordination between project stakeholders.

Clients are increasingly expecting accurate estimations of budget and schedule from project managers, this process can be facilitated by means of BIM and other ERP software. Schedules need to be resource loaded and should have a balance of slack and stretch so as to be efficient without being irresponsible. Furthermore, project contingencies should not be seen as an excuse for overspending as is the case in many cases where managers consider contingencies as part of the budget.

In order to mitigate the effect of the problem listed in Table 2-3, successful project managers need to; Invest in people, understand and manage risk more effectively (Monczka et al., 2009) and learn to adapt to policies and political circumstances (McEwan & Bek, 2006). By adopting integrated BIM's, contractors will be able effectively communicate changes in scope and forecast production requirements in a real-time manner that will increase productivity (Irizarry, Karan & Jalaei, 2013) and promote skills development according to section 2.5 and more specifically, authors *Irizarry and Karan.* Implementing project management software and maintaining a futuristic outlook with regard to the motivation of key resources (as discussed in section 2.5) is also seen as an important role of a project manager (Albert et al., 2004).

The need for skilled labour, planners and project managers

In South Africa, as well as any other developing country worldwide, there exist a significant skills shortage. The most noticeable skills shortage is evident when on-site. The vast majority of work is not completed to an acceptable standard, this is further exacerbated by government driven policies to uplift and up-skill certain communities, as is the case in the WLDC project. The internal skills deficit of a company such as *Company A*, or a main contractor for that matter, is remedied by outsourcing work to subcontractors and specialists. According to discussions with project managers within *Company A,* seven out of ten projects make use of external resources to complete between 10% and 70% of the contract value.

Although according to *Respondent 1*, the lack of skills in the majority of tradesmen hinders successful project execution, the greatest hindrance to project success is the lack of project planners, schedulers and project managers. Many respondents highlighted the fact that sophisticated project management software and information systems are implemented in most projects, however, there is no merit in implementing such systems if the software operator is incompetent or inexperienced. It was also highlighted that within *Company A* the vast majority of planner and schedulers have no formal planning or scheduling qualification but rather go through a month-long training course in a simple project management software such as *Microsoft Project*. A critical task such as planning and scheduling needs to either be outsourced to third-party professionals or delegated to a trained and qualified planner or scheduler.

Effective planning is essential for project success

Successful planning of projects, as discussed earlier, is a vital component of project success along with clearly defined task prioritisation. The majority of interviewees claimed either a design- bid-build or engineer-procure-construct (EPC) approach to construction contracts management are the main contract frameworks used in the construction industry. The vast majority of respondents stated that a thorough contract strategy as well as financial and risk analyses are conducted on projects prior to project approval. Overwhelming evidence, from both respondents and supporting project documentation, indicates that planning is performed on the majority (if not all) projects.

Perception versus Reality

The failure of construction projects to adhere to schedules and budgets is an issue that, for some reason, cannot be easily quantified. The reasons behind such project failures, with respect to budget and schedule are unknown in many projects and are not able to be defined prior to project execution. It may be argued that such erroneous and intangible factors are primarily due to project specific complexities and individuality, however, there is no one project that is completely unique. Each and every single project shares a degree of similarity with other projects.

Although the precise reasons for project failures are so diverse and project specific, there could exist a "global" issue that results in project failure. There exists a misalignment between what project owners, such as *Company A*, perceive and reality. According to a report, conducted by KPMG in 2012, 64% of project owners feel that their management controls are well monitored and optimised while half 55% felt satisfied with their investment in project management (KPMG, 2012).

However, according to the same report, "73% of respondents felt that investment in project governance and controls had reduced cost on projects". When one considers the potential for the reduction of project cost, together with the fact that project owners consistently experience project failures and significant budget overruns, it is evident that project management controls are in-fact ineffective, contrary to what project owners expressed in the KPMG report (KPMG, 2012). According to this very same report, "only 31% of all respondents' projects came within 10% of budget in the past 3 years", while a mere "25% of projects came within 10% of their original deadlines in the past 3 years".

The fact that project owners in the very same report, claimed to have well monitored and optimised project controls, illustrates the degree to which the perception of project owners is skewed. A similar trend exists with regard to risk management, each and every project manager and site engineer interviewed at *Company A* expressed confidence in the fact that risk management should be considered a critical success factor for construction projects. However, they also admitted to, "never being involved with a project that was completely within the original planned budget or schedule", attributing project failures to reasons including but not limited to; incompetent contractors and subcontractors, political pressures to conform to BEE and BB-BEE, poor estimating and tendering processes, industrial actions such as strikes as well as failed risk management processes. According to a senior project manager interviewed at *Company A*, there is a lack of accountability and ownership that exists in South Africa amongst contractors, government, consultants and project owners that has developed into a culture of finger-pointing and blame-shifting. This culture needs to be eradicated before the realisation of successful project management can be realised as no plans, no matter how well executed can be successful without accountability an ownership of stakeholders.

Project approval

Many construction projects, within the South African context, are subject to an extremely unsettling delay before any work has even begun, this delay lies in the approval of the project itself. Once a project has been tendered on and accepted, approval from a board of directors or project owner to initiate the project is required. Only once approval has been obtained can the project commence, this is often a lengthy process that can be up to two years. The effect that such a delay has on a tender is dramatic, market conditions, escalation and interest rates all change during the time between tender and approval. Once a tendering company has placed their tender at a certain time, for a specific set of tasks and for a certain amount, this tender is "cast in stone", however, as mentioned previously, market conditions change between approval and tender, causing a sometimes drastic difference in tender value and costs. To mitigate this effect, escalation and other factors are taken into consideration when assessing tenders that have been subject to drawn-out approval processes, however, such a calculation is extremely complicated and dependent on various variables, many of which are company specific, such as the capacity, cash flow or long-term resource management of a tendering firm.

For instance, a firm could tender on a project based on available capacity, be awarded the tender and only have approval to begin work two years later. In the two years the approval takes, the firm would have needed to make contingency plans in order to make money and to keep their resources busy. After two years, regardless of other projects that the successful tender firm is busy with, the project will commence and the client will expect results despite having kept the tendering firm "on a string" for two years while approval was taking place. Even more so, the client will often expect the same tasks to be completed at the same rate, despite a two year delay and the associated difference in economic conditions. This type of situation ultimately leads to a project that suffers from budget and schedule overruns and often involves numerous cases of arbitration and claims on the part of the contractor. Such an unrealistic tendering policy is the source of many of the common recurring problems encountered on projects and thus needs to be addressed by client companies such as *Company A.*

Claims orientated contracts that are a result of either poor tendering or poor execution result in a project that is difficult to manage and thus lead to projects being over budget or behind schedule according to feedback from a discussion regarding schedule overruns with the project manager of the WLDC project.

5.3 Structured Frameworks

The implementation of structured frameworks such as the SCOR model has undeniable benefits ranging from standardisation of processes to effective communication and cost savings (Rudberg et al., 2013). Made clear by the industry wide acceptance and adoption of SCOR within manufacturing, the benefits of effective structured framework implementation range from financial savings to organisational control. However, based on the information presented in this study, can an existing framework that is developed specifically for manufacturing, be implemented successfully in the construction industry, bearing in mind the complexities of the construction industry?

5.3.1 The SCOR Model

The benefit of implementing a process reference model lies in the fact that complex management processes and plans are able to be dissected into more manageable standard processes. This simplification of processes ensures that the tasks at hand are correctly and strategically implemented, easily measured, clearly communicated and fine-tuned to suit specific situations. One of the contributing factors that limit the success of SCOR implementation in construction is the fact that the construction supply chain varies drastically from traditional manufacturing supply chains. In such traditional supply chains, raw material is delivered directly to the production site where it is transformed into a finished product.

The construction industry, however, has one distinctive difference, the fact that the production site is a temporary construction. This results in the formation of fragmented temporary supply chains and temporary-management-organizations as discussed in section 2.4. Such a supply chain is not conducive to effective information flow or the formation of effective relationships with various stakeholders.

The SCOR model is a fantastic tool when it comes to managing, monitoring and measuring metrics such as Perfect Order Fulfilment, Plan Cycle Time, Cost to Source, Source Cycle Time and Cost to Plan especially when applied in a controlled production environment such as what exists in the manufacturing industry. Furthermore the SCOR model lists best practices associated with each metric, this was discussed in section 0. Although many of the SCOR metrics will not be applicable to the construction industry, there are a select few that are as well as a few that are easily adapted to be applicable to construction. This is in essence the idea behind the builders SCOR model, BSCOR.

The SCOR model could potentially be used as a management tool, used to identify problems construction logistics and supply chain management face. Identification of such problems, especially at an early stage of the project lifecycle, prove extremely beneficial in reducing project costs and schedule delays in later stages of the project life cycle. However, is should be noted that the SCOR model is extremely complicated and is not straightforward to implement in a construction environment and thus such implementations should be thoroughly investigated and planned prior to implementation.

It is unmistakably apparent that the SCOR model was developed for the manufacturing industry and not with the construction industry in mind and as such, the SCOR model should not be considered to be an effective tool for use in the construction industry in its present sate. Alternative structured frameworks should be developed specifically for the construction industry or existing frameworks such as the SCOR model should be carefully adapted to become more aligned with the complexities and challenges of the construction industry.

5.3.2 The BSCOR Model

The BSCOR model, as described in section 2.2.4, is an attempt at developing a structured framework, based on the SCOR model used in manufacturing, specifically for the building and construction industry. This model presents the best and possibly the only opportunity to successfully implement a structured framework that is based on SCOR in a construction project, as it is developed explicitly with construction in mind.

By accepting and accounting for the specific peculiarities that exist in construction, the BSCOR model has the potential to provide a platform from which all construction related projects can be managed, monitored and measured. However, despite the possible potential of such a model, it is yet to be fully developed and thus is not currently a possibility.

5.4 Conventional Project Management

This section serves to highlight the requirements of temporary projects while providing rationalisation concerning the accompanying recommendations. The content and recommendations of this section are based on empirical observation from industry in the form of interviews, discussions, case study results as well as evidence from literature.

As illustrated in Figure 2-7, there are 4 distinct phases in a project, pre-planning, pre-construction, construction and post-construction. Each of these phases are unique in their requirements and management challenges and as such, each will be dealt with individually.

Pre-planning phase

In this phase, the idea for a project should be scrutinised to decide whether its execution will benefit the company and whether the project can realistically be completed. It is acknowledged that planning is not the only project parameter that causes delays and budget overruns, however, planning decisions effect all project attributes and mastering planning will inevitably benefit the project (Nowak & Nowaka, 2013).

Any project requires proper planning, there needs to be a commitment to employ qualified, dedicated planners, not simply someone who has completed a three week training course in a rudimentary project management software such as *Microsoft Project* and claims that they are a proficient planner. Where possible, a dedicated planner needs to be appointed in projects that are deemed strategic to the client company (*Company A*). This will ensure that adequate planning is done prior to tender phase (Fangel, 1984).

A planner should ideally work hand-in-hand with a dedicated scheduler and should be appointed to a single project from start to finish. Although it is acknowledged that such single-project-appointment is not always feasible or practical. Once again, such an employee needs to be adequately trained and experienced in scheduling, although a lack of experienced or even qualified schedulers is an industry-wide problem in South Africa. All project teams should have a highly qualified, bona fide scheduler employed to compile and report on project schedule. Such an appointment should be made in the feasibility stage of a project.

Schedulers and projects in general, need to make use of the latest technology in order to simplify and improve their efficiencies without becoming blindly reliant on software. Software cannot solve all the problems associated with project management. Project management software should be carefully selected, taking into account the competency of its users, the requirements of the project and the capabilities and limitations of the software whilst always remembering that not all tasks can be overshadowed by software solutions.

Complete designs and meticulous planning are key to the success of any project. A resourced schedule needs to be drafted by the clients' team during the feasibility phase. Catastrophic design errors as a result of poorly defined scope or scope changes are unacceptable and lead to large budget overruns and delays. Critical designs need to be completed or at least reviewed by the client as the ramifications of catastrophic design errors for the project are devastating.

The benefit to the client (*Company A*) is in the form of risk reduction and ensuring such designs are correct far outweighs the cost of the designs themselves according to evidence obtained during a progress meeting at the WLDC project during 2015. Designers' programs should be integrated with the construction program to ensure critical designs are completed prior to actual construction activities commence. This goes hand-in-hand with the need for an improved approval process as discussed earlier, a design approval should not take 2 weeks, and rather, it should take 2 days. If the approval process is deemed to be an extended period of time, then a realistic timeframe should be allowed for in the schedule. Such processes should be based on historical data (Persson & Araldi, 2009; Makris et al., 2011) and project-specific experience and should implement a communication matrix for effective progress reporting in this regard.

Pre-construction phase

This is the phase where the budget and schedule should be determined and resources allocated to tasks, this is where it is imperative to appoint a dedicated planner and scheduler, as poor calculations at this early stage prove extremely costly later on in the project, according to an interview with the project manager of the WLDC project. A schedule needs to be reviewed and amended by as many stakeholders as possible before being finalised and compiled by a competent scheduler. All schedules that are to be used for operational, management or measurement purposes should be resource loaded.

Since a great deal of project complications arise in the delayed process of project approval, especially when the client is a large corporation as is the case with *Company A*, the project approval process as a whole needs to be reviewed and adapted in order to ensure that a tender from two years ago is applicable in the present. Market and economic conditions need to be evaluated both at the time of tender and at the time of project initiation as well as considering the appointed firms' requirements and in-house dynamics such as capacity and cash flow. This should limit effects on projects similar to those experienced on the WLDC project, where an estimated R 20 million escalation and twelve month delay was as a direct result of inadequate planning of an EIA. The capacity of EPCM consultants and contractors also needs to be established before any work is awarded to a firm that is unable to provide an adequate service.

A resourced schedule should be drawn up for all projects by the abovementioned scheduler. A resourced program lends itself to scrutinising given schedules in relation to an achievable schedule, this furthermore prevents schedules from being overambitious and unrealistic and allows for the integrity of the schedule to be meticulously scrutinised. Such resourced scheduling should become an industry standard that can be used to assess tendered schedules, thus making a resourced schedule a tender requirement for both contractors and subcontractors.

This process will encourage in depth planning on the part of tenderers that will in turn lead to more accurate tenders, better schedule and budget adherence and ultimately a more efficiently managed project. It is imperative that the client is aware of the schedule and as a result, should be required to sign off and approve the schedule to highlight their understanding and support of the schedule and to accept the associated risk of a particular schedule.

Construction phase

A large proportion of schedule delays and budget overruns on construction projects are as a result of scope changes, albeit due to necessary changes, material shortages or weather problems (Ciutiene & Meiliene, 2015). It is recommended that once a project is put out for tender that the scope be "frozen", this is known as scope freeze. Scope freeze allows tendering firms to tender accurately and provides a clear outline of the exact work to be completed. Any scope changes should be signed off by the project sponsor or "client" and should be subject to a structured change management process with transparency to all project stakeholders. This certainty reduces the degree of risk that contractors are exposed to and thus results in realistic tenders.

Furthermore, in the mining sector, the red-tape associated with being granted access to a site is a major factor that needs to be considered by firms that are unfamiliar with the mining sector. Such mining-specific red-tape was acknowledged in the WLDC case study where it was documented that induction and so-called "ted-tickets" took up to two months to acquire. This is essentially lost time as the contractor has already committed to a deadline and schedule and thus needs to be considered when dealing with any scheduling activities at earlier stages of the project. Such significant time losses can be mitigated by means of on-site medicals by means of satellite facilities, allowances in contractual documentation as well as foreword planning in this regard.

The mining sector specifically, has extremely high safety standards and requires in depth medicals, safety training and protracted induction processes that are uncommon in the construction sector. As a result, companies doing work in the mining sector need to take into account the extreme cost of such requirements as well as the timeframe required for successful completion of such requirements.

In order to facilitate uninterrupted material supply, contractors and consulting engineers should collaborate and develop a *project commodity schedule* that lists preferred suppliers and provides suppliers foresight as to the demand and technical requirements of each order. Such forward planning enables suppliers to schedule production based on actual real-time lead times. Another important conclusion of both the literature study and case study is that, particularly in a developing country like South Africa, suppliers and tenders should not be selected based solely on price but should rather be selected based on capacity, capability, reputation, price and quality. This rationale is supported by evidence presented in section 2.3.1, where the consequences of cost-based and BBBEE-based vendor selection is discussed. If a contractor insists on using a supplier that is deemed unfit by the client, the contractor should be held liable for any delays or extra costs that may arise as a direct result of that supplier.

Within the South African construction environment, there has to be contingencies made for weather, strikes, approvals and scope changes by both the client and contractor. This is non-negotiable as none of these risks can be managed in terms of probability or impact analysis by means of conventional project management or supply chain management theory.

Post-construction phase

The movement and turnover of key personnel should be avoided on all projects and especially so on projects of strategic importance to the company. Key personnel should be appointed to a specific project on a start-to-finish basis in order to take advantage of the fact that such personnel have the required knowledge of the project, its intricacies and project specific challenges. Such experience along with personal relationships with suppliers, contractors and other stakeholders forms the basis for the successful management of a project. Constant changes to key management staff results in project delays (Quayle, 2006) and when possible should be avoided according to *Respondent 2* of the expert review and the *Project Management Institute*.

Contracting models

The contracting model that is used for a project is an extremely important consideration and is directly linked to the ability of a project to adhere to a specified schedule and budget and ultimately, contributes to the success or failure of the project.

Every model has its place while certain models are preferred by particular companies simply for the sake of standardisation. Regardless of the model, contract documentation needs to be clearly communicated (Agapiou, Flanagan, Norman & Notman, 1998) by a designated document controller. This was agreed to be a viable option according to a project manager at *Company A*. Contractual documentation should be seen as a safety net for both the client and the contractor, security against their commitment to provide a job or service in an certain time-frame for an agreed upon fee.

In the mining sector, the FIDIC (International Federation of Consulting Engineers) contract is widely accepted as being the best model and is preferred over models such as the JBCC contract (Joint Buildings Contracts Committee). The JBCC contract has a short reporting period on defects which makes it unsuitable for the mining sector as lead times are long in the mining environment due to the red-tape that is associated with all activities and the often specialised nature of construction in such environments.

It is imperative that stakeholders who base their decisions on and are directly affected by the contents of a contractual agreement receive the adequate background and training with regards to a specific contractual model. It should be noted that the SCOR model makes no explicit reference to the selection, measurement or management of contractual agreements or different contracting models.

Chapter 6. SCM Implementation Considerations

This chapter is concerned with building on the findings and discussion topics of *Chapters 4* and *5* by means of further investigation into the concept of an alternative approach to project management or a hybrid management approach in the construction industry. This chapter presents the current state of the construction industry and evaluates the opportunity that exists for SCM in project management.

6.1 The shortcomings of conventional project management practice

There exist many shortcomings in project management, each attributed to a certain root cause. It should be noted that project management is not a management science involving specific techniques and "magical-management-tools", it is simply a philosophy of management. Listed in the following section, are the most commonly cited issues that arise in the project management realm.

Appointing the correct person for the role of project manager

The role of a Project Manager (PM) is allocated during the early stages of a projects inception, there is not enough consideration given to the type of person that will be the PM (Ahadzie et al., 2014; Hadad, Keren & Laslo, 2013). A projects success is to a large degree dependent on the PM, making the PM an extremely important resource. PM selection is often based on availability and not on personality type or skill set. Without a suitable PM, team members often have no sense of ownership towards a project as project expectations and delegation of responsibilities are not clearly defined or communicated.

The solution is to appoint a PM who is passionate about the project and whose personality, skills and experience are in line with the project at hand (Mazur & Pisarski, 2015). A study conducted by means of a survey, questioned project management practitioners from different countries and projects to establish that certain personalities are better suited to the role of project manager than others, according to the *Myers-Brigss Type Indicator* (MBTI) that is commonly used in psychometric questionnaires. According to the study, "the most successful project managers usually are extrovert, thinkers and judgers (Montequin, Nieto, Ortega & Villanueva, 2015).

Turnover of key human resources

It is the role of the PM to convince the project sponsor and high-level management that certain resources are key to the relative success or failure of a project to ensure that such a resource is not transferred to another project halfway through a project (Savolainen & Ahonen, 2015). The loss and sharing of critical human resources between projects can result in budget overruns and schedule delays.

The solution is to ensure that high-level management agrees to a certain minimum tenure for key human resources, subject to company policies. Numerous researchers have higher turnover rates with Generation Y employees compared to other generations in a variety of industries, including construction (Burke, 2004; Lancaster, 2004).

Failure in achieving project team buy-in

Projects often fail because they fail to get enough support from the stakeholders and people affected by and involved in the project. Clear role definition, a sense of urgency, personal incentives and an intrinsic value motivators in the project are important to achieving successful project management.

PM's first order of business should be to arrange a team meeting where the significance and value of the project is communicated to the entire team. Failing to get buy-in from executives in a project is not the duty of the project manager, this is the duty of higher level management (McEwan & Bek, 2006).

Performing too many projects at once

It is a common misconception of many PM's to think that they can achieve higher productivity by starting all tasks at once, according to *Mr Messinger* of *ipsolutions*. However, this has been proven to be unproductive by both the very theory of TOC and by *Goldratt* (1997). Multitasking inherently leads to lower efficiency of human resources while diminishing quality of work as well as causing delays that have a "ripple-down" effect on the entire project.

The solution is to reduce the work that is in progress, take a step back and focus on certain critical tasks (Zheng et al., 2014; Goldratt, 1997). This approach to management ensures that resources are productive and well-motivated while frequent project completion instils a sense of pride and momentum into a project team according to a psychological study (Cardoso, Dominguez & Paiva, 2015).

Lack of communication

Project teams in the twenty-first century are often multi-cultural and multinational, this leads to certain communication challenges that did not necessarily exist twenty years ago. Scheduling meetings when taking into account different time zones around the world becomes a challenging task, never mind the need to consider different cultures and languages.

Communication is an important factor of successful project management (Attarzadeh & Ow, 2008) and without good communication, a project has a high probability of failure (Van Heerden, 2013b). In addition to regular scheduled meetings, a project manager should be proactive in communicating on both a business and personal level with their human resources, according to a junior site engineer of a contractor working for *Company A*, stating that "project management is all about interacting with people".

Allowing the scope to frequently change, scope creep

Without a clearly defined goal and scope, project management of a project becomes complex. One of the three most common causes for schedule delays and budget overruns at *Company A*, according to a senior commercial manager at *Company A*, is scope change. The change in scope causes unplanned delays, there are no contingencies for scope change and thus each and every scope change results in management issues.

The scope of a project needs to be clearly defined and before tendering, needs to be "frozen". Scope freeze and clearly defined resourced schedule will enable the PM to manage the expectations of the client and if any changes to the scope are effected, the client will be responsible for such changes and the financial implications that follow.

Commitment to an overly optimistic schedule

In an attempt to keep clients happy, PM's often go against their better judgement and commit to an unrealistic or existing schedule due to external pressures from senior managers or the client (Savolainen & Ahonen, 2015). Once deadlines are missed, there is a sense of distrust and aggravation on the part the client and his representatives. Such situations need to be managed by the project team and PM by reinforcing their planned schedule with facts. A detailed and resource loaded schedule that is produced in a well-known software package will allow the PM to illustrate to the client the reasoning behind certain schedules, buffers and contingencies.

Not being able to track changes

Often project have no change management system in place for approving and tracking changes (Whyte, Stasis & Lindkvist, 2015).
Each construction project is unique in some or other way and thus each project needs to be managed in a specific manner, there exists no one-size-fits-all solution to project management.

According to PMBOK (pg. 94 & 126), the solution is to ensure that there exists a clear change management procedure to deal with changes on projects. Outdated software such as *MS Project*, *PowerPoint* and *Excel* are all used extensively in managing and monitoring projects and project performance. However, cloud-based management software and BIM that allow real-time progress updates, change management functionality and enable collaboration are available but not yet implemented as a requirement on most construction projects (Hornstein, 2015).

Micromanagement of projects

The onus to perform a task or responsibility should be on the individual human resource instead of the project manager in order to limit micromanagement. There should be regular scheduled update meetings throughout the duration of the project to ensure that human resources take ownership of their responsibilities.

Defining success

One of, if not the most important measure of a project needs to be the criteria for success measurement (Albert et al., 2004). There needs to be a metric that can be measured in order to determine the success of a project upon project completion. Be it cost, time or something more project specific, there needs to be a measure that will define success so that all stakeholders can walk away satisfied in their achievement. Without such a metric, the success of project cannot be measured and therefore it cannot be managed.

6.2 Metrics for measuring project management performance

The selection and implementation of key metrics, also known as KPI's, is an essential part of achieving effective control and management of construction projects. There are however, many challenges that face the selection and implementation of such metrics. The first challenge is being able to establish a culture of measurement within an organisation or project team. This involves achieving buy-in by top management that sets the foundation for the establishment of a formal approach towards measures and metrics. Such continuous reinforcement from management will allow the facilitation of such measurements of KPI's to be deemed important by all involved.

Another major challenge that faces the implementation of metrics and measurements is the lack of data and data validation in the construction industry. Such a lack of data is a result of both poor training and poor management philosophies. Without correlation between metrics and projects outcomes, coupled with the fact that there exists no formal approach towards the measurement of metrics and a lack of support from top management, the construction industry will not benefit from measurement and identification of metrics.

There needs to exist a clear governance process for the measurement and identification of KPI's that is developed early in the project to allow for support and ownership of the process by top-level management and project stakeholders.

Before data collection can begin, metrics need to be identified at an early stage of the project in order to assess the effort and cost of measurement of the metric, the availability and reliability of industry benchmark information as well as the financial quantification of such a metric. Financial quantification is an important consideration when choosing project metrics as this translates to the effect on the bottom-line and without a strong motivation as to the possible financial benefits of measuring a certain metric, buy-in by top level management will be challenging.

When deciding upon which metrics are to be measured in a certain project, it is imperative that the goals of the project correlate with the metrics that are to be measured. Metrics should serve to mitigate project issues, track progress, detect variances from the original project plan and serve as an "early warning system" for managers to use to diagnose project problems and the origins thereof. Thus, each metric should be carefully selected for each project based on specific challenges and peculiarities unique to each project.

An example of commonly measured project metrics as per the PMBOK project management approach are as listed in Table 6-1.

Table 6-1: Commonly Implemented Project Management Metrics

Attribute	Measured Metric	Description
Cost	Present Cost	Overall cost-to-company at a certain time
	Earned Value (EV)	Budgeted cost of work performed
	Present Value (PV)	Present value of invested capital
	Estimate at Complete (EAC)	Final cost at completion
	Cash Flow	Ratio of money in to money out of a project budget
	Budget Critical Tasks	# of tasks almost over budget
	Over Budget Tasks	# tasks that are over budget
Schedule	Schedule Variance (SV)	Cost of progress vs. cost of planned progress
	Activity Complete Percentage	Percentage complete of a certain activity
	Schedule Remaining	Time available to overall project
	Milestones	Specific points in a project
	Schedule Performance Index (SPI)	Ratio of work performed to work scheduled
	Overdue Tasks	# of tasks that are behind schedule
Resources	Response time	Time to respond to a request
	Capacity	The maximum rate at which work can be performed
	Resource availability	Resource availability = Capacity – Idle time
	Over allocated Resources	# of resources assigned to more than one task
	Idle Time	Time resources are idle
Project Execution	Scope Change Requests	# of scope changes requested by the client
	Scope Change Approvals	# of scope changes approved
	Rework	# of units of rework
	Staff Turnover	# of project team members that quit or were reallocated
	BBBEE Ratio	Ratio of BBBEE contractors to non-BBBEE contractors
	Induction/Approval Process Time	Average time taken for staff to be inducted and approved to work on site

As project metrics provide information regarding the performance of a project, these metrics form an important source of data for project control. As such, each metric requires a robust definition, a means of measurement, a method for analysis and a baseline reference in order to prove effective in evaluating project progress, reducing risk and forming a basis for project control.

The means of measurement of a metric is of critical importance and it should be clearly defined how a certain metric shall be measured and analysed and how frequently. The data gathered pertaining to a specific metric needs to be processed and then used to make informed decisions based on this feedback, as such, the communication of such metrics is important to consider.

Metrics should not be chosen based on accepted practice or frequency of use but rather on the specific requirements of each individual project.

6.3 Opportunities for SCM Implementations

There exist examples where the use of conventional project management techniques are not effective nor successful in adequately managing certain on-site activities. In such cases, do there exist SCM principles that can be applied in the construction environment to manage such situations? Furthermore, it needs to be established whether such solutions are capable of facilitating a significant improvement in project management in construction projects in order to be deemed feasible.

Many instances of project management could potentially be better executed by means of direct application of SCM principles or by adopting a SCM approach to the process of managing a specific task. However, selection of such generic tasks is problematic due to the unique nature of each and every construction project. For instance, SCM has proved, in the manufacturing industry, that its structured frameworks and well-defined metrics are applicable to training of personnel, facilitating collaboration amongst stakeholders and successful in the management of purchasing, transportation, materials handling and defect returns, to name a few.

6.3.1 The SCOR Model in the Construction Industry

As discussed in section 5.3.1, SCOR involves capturing and detailing of "as-is" processes in an effort to derive a desired future process and quantifying operational performances of other businesses in order to establish benchmark targets that will allow for competitive advantage over the competition. This is achieved through the implementation of management practices and software solutions that are industry leading and will allow for optimal performance. The model is aimed at achieving effective communication amongst supply chain partners by providing a standard mode of communication and ultimately measure, manage and evaluate supply chain configurations. SCOR aims to simplify complex management processes into standardised processes that are easily communicated, managed and controlled.

SCOR is an exceptionally powerful tool that has the potential to restructure and improve complex management processes and has been proven by its wide range of implementations throughout the manufacturing and logistics world. However, as discussed in section 5.3.1, in its current state as the Supply Chain Operations Reference model, this model is not industry specific enough to be able to be applied in an environment that is as dynamic and complex as the construction industry.

Rather, a specialised framework needs to be developed, following a similar logic to that of the SCOR model but taking into consideration the many peculiarities that are exclusive to the construction industry. As discussed in section 5.3.2, such a model is currently in development known as the BSCOR model that is directly applicable to the construction industry and considers the various construction specific issues that hinder the effective implementation of the SCOR model within the construction context.

Yet another fundamental issue that exists with the implementation of SCOR is the across-the-board collaboration that is required to take full advantage of the SCOR model. Suppliers, contractors, architects, engineers and clients all need to collaborate in order to benefit from SCOR which is not currently possible in the South African construction industry. The reasons being that historically the construction industry is not a collaborative environment, it is extremely expensive to implement (Gyllin & Thunberg, 2010), there is no confidence in the SCOR model as far as industry is concerned and more importantly, due to the fact that the model is complex and cumbersome to implement.

6.3.2 Manufacturing and Construction

Manufacturing is all about mass production. Modern day manufacturing is centred on the needs of the customer, a market where product customisation is competitive advantage. Product customisation is in the realm of construction where essentially every “product” that is produced in this industry is made to specification and is entirely customised. Modern-day-construction is striving to adopt mass-production approach of manufacturing in order to capitalise on economies of scale and reduce project complexity whereas manufacturing industry is moving away from mass-production into a more personalised, customisation-production-process, similar to production in the construction industry (Winch, 2003; Dubois & Gadde, 2000).

Manufacturing has changed significantly form the mass production, where price was seen as competitive advantage and customisation was non-negotiable to modern day manufacturing where customisation and social responsibility are king and price is no longer the only market driver. In the old days, mass production was synonymous with manufacturing, manufacturing is synonymous with minimizing waste, maximising value, eliminating defects and reducing the environmental impact of production materials and production methods in a socially responsible and sustainable manner (Garcia, Marchetta, Camargo, Morel & Forradellas, 2012; Stindt & Sahamie, 2012).

Where in the past, construction was deemed to be able to learn from manufacturing, the converse is true in the twenty-first century market. According to *Winch*, “construction is no longer seen as backward and antiquated but rather as being different from manufacturing (Winch, 2003).

The major differences are that modern day construction is a complex system; there exist many variables that influence the construction process; construction is location based and on-site; a construction project often employs in excess of 500 human resources, significantly more than manufacturing and furthermore, construction entails a degree of social responsibility that does not exist in general manufacturing.

Thus the future challenges that face the manufacturing industry are already being addressed in construction. Many elements of construction should draw from the lessons of mass-production whilst the modern-day mass-customisation market of manufacturing should in fact learn from the lessons learnt in construction. One example of manufacturing principles is off-site production, also known as prefabrication and shall be discussed further in the following section (Winch, 2003).

6.3.3 Prefabrication

Manufacturing processes do not provide the solution top all of the problems experienced in the construction industry as was expected at the start of this study, although the implementation of various manufacturing principles and methodologies in the construction industry is a feasible solution to many of the issues that plague the quality and efficiency of construction as well as capitalizing on the paybacks of economies of scale and better control and management.

It should be noted that manufacturing principles cannot be directly applied to the construction industry in a hope that it will solve a similar problem to that in the manufacturing industry. Such solutions need to be specifically tailored to suit the intricacies and peculiarities of the construction industry. Prefabrication addresses many of the major challenges that are faced by the construction industry; waste generation, sustainability, quality, skills development as well as schedule and budget adherence.

Waste generation is limited at an on-site production facility that operates under controlled conditions where recycling and reuse is made easy. Reduction of waste in turn addresses the sustainability issues of construction. By manufacturing components of structures at an off-site location, the quality control of elements is significantly better than that of on-site in-situ construction, an important fact as this reduces the amount of rework on a project that in turn significantly reduces the cost of the project.

Projects that make use of prefabrication initiatives employ fewer human resources on-site but the off-site jobs that are created are generally permanent. Such jobs allow for effective skills transfer through a structured skills development program whilst ensuring better and safer working conditions and greater job security. Prefabrication can help the construction industry move away from an *engineer-to-order* industry where there exist many unknowns and involves significant customization, to a *make-to-order* or even *make-to-stock* industry.

Prefabrication allows for advanced integration of Building Information Models (BIM) in the management of construction processes and for effective information sharing between various stakeholders. According to a senior commercial manager at *Company A*, who has extensive experience in construction projects and has been involved in mega-projects such as the *Gautrain*; BIM is the future of the construction industry and will become a standard requirement in years to come, thus implementation of a construction process that lends itself to BIM is an important constituent to project success.

Aside from direct applications of SCM principles per say, SCM ideologies, such as the approach SCM takes to achieving collaboration, effective communication, foreword planning, waste reduction and optimisation of tasks, has the potential to be applied to the way in which high-level project management is conceptualised and executed.

For instance, if a "SCM mind-set" was to be adopted by construction professionals with regards to implementation of cutting edge technology, BIM would be implemented across-the-board in the construction industry. The cloud-based management systems, real-time updates and monitoring functionality, integrated logistics processes and collaboration framework that BIM software provides would be taken full advantage of in a manufacturing environment in order to manage the entire supply chain in a more efficient manner. BIM involves employees in a collaborative and visual manner, allowing them to measure and understand the effect of their actions on the project as a whole, in a country where literacy rates and skill levels are low, such an interactive communication and training mechanism could be extremely successful for training purposes.

Construction, however, does not cultivate the same drive for innovation and optimisation as the manufacturing industry does (Friedman, 2015). SCM ideologies such as information sharing and collaboration benefits all the stakeholders involved in the construction process and allows transparency within the construction supply chain and construction process.

How then, can the construction industry involve SCM in the management of projects, if not through a direct SCM implementation, then in the very manner in which such projects are managed?

6.3.4 The Value of SCM within Construction Management

It is difficult to quantify the potential value that a SCM approach to managing construction projects may have. It is the intention of this section to highlight the value, the potential, that exists in adopting a SCM approach to managing projects, if not exclusively, then as a supplementary approach to conventional PMBOK project management approaches and methodologies.

Typical construction problems are listed in Table 6-2 along with conventional project management solutions, SCOR focus areas and Supply Chain Management approaches to effectively manage such problems.

Table 6-2: Solutions to Common Reoccurring Construction Issues

Common Construction Problem	PMBOK Solution Approach	SCM Solution Approach	SCOR level 1 Processes/ Metrics
1. Behind schedule	Crash tasks to shorten the *Critical Path*	Inventory buffering systems and process modelling and reengineering. ABC inventory management	sP2 – Plan Source
2. Over budget	Enforce more severe cost control	Alternative Sourcing Procedures/ supplier selection	sP1 – Plan Supply Chain
3. Poor stakeholder management	Manage stakeholder expectations by identifying and understanding their	Choose and focus on competitive advantage of company. Manage expectations from early stages of project	sE6 - Manage Supply Chain Contracts

	requirements in the pre-feasibility phase		
4. Insufficient communication	Conduct structured concise meetings as part of a project communication plan. Ensure project managers are "peoples people"	Collaboration amongst stakeholders is a core focus of SCM to eliminate silo-management	sE3 – Manage Supply Chain Data and Information
5. Poor project planning	Ensure sufficient time is allocated to planning as effective planning will improve the odds of project success	Emphasis on collaborative design results in better planning, incorporating all stakeholders input. Planning the delivery of buffers is important	sP4 – Plan Deliver
6. Poor construction requirements	Ensure that the scope is based on project requirements	Poor requirements are the result of poor planning	sP3.3 – Balance Production Resources with Production Requirements
7. Inaccurate estimates	Base estimates on a combination of qualitative experience and quantitative historical data	Ensure estimates are in line with a selected business strategy. Estimation is about trade-off between attributes, i.e. cost and time	Choose competitive advantage performance attribute, evaluate estimates based on selected performance attribute
8. Poor software implementation	Ensure software operators are well trained and understand the process executed by the program. Do not use software blindly	Select software based on the requirements of all stakeholders. There needs to be integration between software operators and the end user of the information generated from software	N/A
9. A lack of risk management	Ensure risk management is executed continually, making use of established risk management methodologies	Identification, quantification and management of risk is an integral part of successful SCM and SCOR implementations. Supply Chain Resilience is considered	sE9 – Manage Supply Chain Risk AG.1.3 – manage value at risk
10. No quality assurance/poor quality	Continual monitoring of completed work as per SANS standards	Constant monitoring of incoming product quality results in improved quality work. Ensuring that the performance attribute of	RL2.4 – Perfect Condition

		the project is in line with expected quality	
11. Problems making decisions	Ensure decisions are SMART and are made by following the correct decision making process	Ensuring the correct skills are applied in the correct role. SCM provides structured processes and best practices for dealing with issues which makes decision making simplified.	sP3 – Plan Make
12. Constraints identification	Collaborate with stakeholders in the planning phase to clearly define project constraints	Planning phase collaboration results in effective constraint management. TOC approaches explicitly identify constraints and	sP2.3 – Balance Product Resources with Product Requirements

There exists sufficient evidence in literature that suggests that there is value in implementing SCM within the construction environment, more specifically, in the management of projects.

Table 6-1 presented commonly implemented *PMBOK* project management metrics while Table 6-2 presented a summary of conventional and SCM approaches to common construction issues.

Table 6-2 is originated from empirical evidence obtained through a series of five interviews and discussions with "Industry Experts" and serves as evidence to suggest that there may be value in SCM principles within the project management environment. These industry experts were deliberately sourced from industries and companies outside of *Company A*.

Common management metrics in the SCM field as well as their relation to the more industry-specific BSCOR model are as listed in Table 6-3. It should be noted that all of the listed metrics and the definitions thereof are as per metrics outlined in SCOR, available at; http://www.apics.org/sites/apics-supply-chain-council/frameworks/ scor. Furthermore, definitions of the BSCOR metrics, processes and best practices as discussed in the below section are available at; http://bscor.com/.

The list of prevalent metrics in the manufacturing industry can be regarded as potential metrics for project management of construction projects and their relation to the BSCOR model is important as the this model serves as the only current direct link between the manufacturing and construction industries.

Table 6-3: SCM Metric Prevalence in BSCOR

	Metric	BSCOR Processes										
		Source Construction Materials	Source Resources	Source Subcontractor Materials	Build Contractor	Build Subcontractor	Plan Source Contractor	Plan Source Subcontractor	Balance Sourcing Plans	Plan Build Contractor	Plan Build Subcontractor	Balance Production Plans
Metrics	Order Fulfilment Cycle Time	X	X	X	X	X	X	X	X	X	X	X
	Build Cycle Time				X	X						
	Source Cycle Time	X	X	X								
	Plan Source Cycle Time						X	X	X			
	Make cycle time											
	Deliver cycle time											
	Perfect order fulfilment											
	Yield (Output/Input Ratio)											
	Downside supply chain adaptability											
	Downside build Adaptability,				X	X						
	Overall value at risk											
	Upside build Adaptability,				X	X						
	Upside supply chain adaptability											
	Upside supply chain flexibility											
	Upside Build Flexibility				X	X						
	Cost to Build				X	X						
	Material Transportation Cost											

	Cost to Source,	X	X	X								
	Cost to Serve											
	Product Acquisition Costs	X	X	X								
	Sourcing labour Cost											
	Energy Cost per Unit									X	X	X
	Energy consumption									X	X	X
	Sourcing Property, Plant and Equipment Cost											
	Cost to Plan Source						X	X	X			
	Cash-to-Cash cycle time				X	X	X	X	X	X	X	X
	Inventory Days of Supply (Raw Material)	X	X	X								
	Return on working capital	X	X	X	X	X	X	X	X	X	X	X
	Inventory Days of Supply (WIP)				X	X						
	Number of Movements of Construction Materials				X	X						
	Return on Supply Chain Fixed Assets	X	X	X	X	X	X	X	X	X	X	X
	Return on supply chain fixed assets											
BSCOR Best Practices	Goods reception	X		X								
	Lean Construction				X							
	Building Information Modelling				X	X	X	X	X	X	X	X
	Last Planner				X		X	X	X	X	X	X
	Line of Balance				X	X	X	X	X	X	X	X

As per the BSCOR information presented in Table 6-3, metrics that will be considered important for consideration in the management of construction projects are; Order Fulfilment Cycle Time, Build Cycle Time, Source Cycle Time, Plan Source Cycle Time, Cost to Source, Product Acquisition Costs, Cash-to-Cash Cycle Time, Inventory Days of Supply (Raw Material), Return on working capital, Return on Supply Chain Fixed Assets.

Best practices that are to be investigated further for incorporation into the management of construction projects are; Building Information Modelling, Last Planner and Line of Balance.

These metrics and best practices will be considered as possible SCM alternatives and/or additions to PMBOK metrics and were evaluated by means of expert consultation in the construction industry as summarised in Table 6-4.

Only metrics that were selected by three or more of the expert respondents were considered as applicable to this study as well as any metric that was deemed to be a "top 5" metric. The list of metrics presented in the table below can be seen as the most applicable metrics for use in the construction industry as per the panel of experts that were consulted in this regard.

A complete list of "Industry Expert" respondent summaries are presented in *Appendix B*.

Table 6-4: Construction Industry Validation of Appropriate Project Management Metrics

Proposed Metric	Respondent Summary				
	Applicable	Measurable	Top 5 Metric	Currently measured	Will improve cost and schedule?
1. Order Fulfilment Cycle Time	X	X	X	X	X
2. Build Cycle Time	X	X	X	X	X
3. Source Cycle Time	X	X	X	X	X
4. Deliver cycle time	X	X	X	X	X
5. Cost to Build	X	X	X	X	X
6. Cost to Serve	X	X	X	X	X
7. Energy Cost per Unit	X	X	X	X	X
8. Cash-to-Cash cycle time	X	X	X	X	X
9. Return on working capital	X	X	X	X	X
10. Inventory Days of Supply (WIP)	X	X	X	X	X
11. Number of Movements of Construction Materials	X	X	X	X	X

Table 6-5 serves as a summary regarding the extent of overlap that exists between the manufacturing and construction environment by comparing the use of metrics in each specific industry body of knowledge as well as in specific companies that operate within the South African construction industry. This table serves to orientate the reader concerning the extent of the overlap between manufacturing and construction.

It is evident from the information presented in “Bold” text in Table 6-5 that construction projects are mainly concerned with monitoring metrics that relate to cost and time.

No direct reference to the vast majority of metrics presented in Table 6-5 is made in the PMBOK framework, however, build cycle time, cost to build, cost to source etc. are metrics that are poignantly in line with the recommendations of BSCOR metrics. This observation serves as a validation of the applicability and correctness of the BSCOR model to the construction industry.

Common PMBOK metrics include but are not limited to on time performance, production rate, daily input costs, daily production revenue earned, failure rate, resource availability, budget control, machine process cycle time and standing/breakdown time.

Work performance metrics from PMBOK include planned cost, actual cost, planned performance, schedule performance and technical performance. PMBOK advocates measurement of these metrics as an important constituent of project success but does not, however, prescribe definitive metric definitions in the form of a list of metrics that are applicable to certain projects or certain contracting schemes.

The full potential of PMBOK is thus not completely realised as there exists no standard measurement metrics that are consistently measured and monitored in a project other that those listed previously. The expected results of SCM implementations include, but are not limited to the benefits listed in Table 6-6.

Based on the evidence presented in Table 6-5 regarding the overlap that exists between project metrics as well as expert validation information presented in Table 6-2, Table 6-3, Table 6-4, together with consultation of commonly cited literature that is presented in *Chapter 2*, a summary of suggested project metrics that are applicable to the construction industry are presented in Table 6-7.

Table 6-7 serves as the culmination of all the information regarding SCOR and BSCOR metrics and forms a preliminary suggested list of project management metrics that are both measurable and applicable to the realm of construction and are considered to be important for consideration in the management of construction projects.

Table 6-5: SCM Metric Prevalence in the Construction Industry & Knowledge Areas

	Metric	Industry Knowledge Areas			Organisations directly involved in the construction industry		
		PMBOK	SCOR	BSCOR	*Cobute*	*Stellenbosch University*	Stefabutti Stocks Marine Division
Responsiveness	**Order Fulfilment Cycle Time**		**X**		**X**	***X***	**X**
	Build Cycle Time	**X**		**X**	**X**	***X***	**X**
	Source Cycle Time		**X**		**X**	***X***	**X**
	Plan Source Cycle Time		X				
	Make cycle time		X			*X*	X
	Deliver cycle time		X			*X*	X
Reliability	Perfect order fulfilment		X			*X*	X
	Yield (Output/Input Ratio)	X	X			*X*	X
Agility	Downside supply chain adaptability		X				
	Downside build Adaptability,			X		*X*	
	Overall value at risk		X				
	Upside build Adaptability,			X			
	Upside supply chain adaptability		X				
	Upside supply chain flexibility		X				
	Upside Build Flexibility			X			
Cost	**Cost to Build**	**X**		**X**	**X**	***X***	**X**
	Material Transportation Cost		**X**		**X**	***X***	**X**
	Cost to Source,			**X**		***X***	**X**
	Cost to Serve		**X**		**X**	***X***	**X**
	Product Acquisition Costs			X	X		X
	Sourcing labour Cost		X			*X*	
	Energy Cost per Unit	X		X			X
	Energy consumption	**X**		**X**	**X**	**X**	**X**
	Sourcing Property, Plant and Equipment Cost	X	X				X
	Cost to Plan Source	X		X	X		
Asset Management Efficiency	**Cash-to-Cash cycle time**	**X**	**X**	**X**		**X**	**X**
	Inventory Days of Supply (Raw Material)	**X**		**X**	**X**	**X**	**X**
	Return on working capital	**X**	**X**	**X**		**X**	**X**
	Inventory Days of Supply (WIP)	X		X	X	X	
	Number of Movements of Construction Materials			X			X
	Return on Supply Chain Fixed Assets,	**X**	**X**	**X**			**X**

Table 6-6: Benefits of SCM implementation in construction

Benefit	Description
Profitable growth	SCM contributes to profitable growth by facilitating collaboration amongst stakeholders. This directed communal approach to solving problems and sharing information improves the efficiencies of problem solving. In construction, profit margins are generally small, so a small reduction in supply chain waste can increase the profitability of a company (Venkataraman, 2004; Chen, 2011).
Foresight	By adopting a supply chain approach to training of personnel, especially in the South African context, where there exists pressure to train employees to successfully execute the task that they have been assigned, companies will be able to arrange training of staff prior to project execution. This streamlining has the potential to save significant time, as delays experienced as a result of poor workmanship, absenteeism and on-the-job-training will be significantly reduced. The knock-on effects of such delays will in turn be eliminated, contributing to further time saving and a more responsive operational strategy that allows for capitalisation on opportunities.
Working-capital reductions	Accelerating the cash-to-cash cycle of a project will reduce the required working capital of the project. This is achieved through optimisation of resources as well as structuring of management processes.
Fixed-capital efficiency	Ensuring that a company has the correct personnel, correct number of deployed assets in the correct locations, doing the correct activities is essential in achieving effective capital efficiency.
Standardisation	By implementation of a SCOR or BSCOR structured framework, communication and management of projects becomes a “plug and play” situation, where a series of steps are followed in a logical and formalised manner, based on industry best practice. Standardisation further supports collaboration amongst the project team and project stakeholders.
Measurement and control	By measuring a select few project metrics, project managers are able to focus on specific metrics and use the information regarding such metrics to make informed decisions regarding the project. Selection of fewer critical KPI’s is essential in reducing the complexity of PMBOK project management. By knowing what to measure and how to measure it, adequate management processes can be put in place to improve the performance of a metric and consequently a process or task.
Reduction of complexity	SCM principles and processes are often well organised in a logical and structured manner. This is an important consideration when considering the amount of rework and management challenges that arise from the complexity of project tasks. By implementing a standard operating procedure throughout the construction process and through implementation of structured frameworks that feed of a global body of knowledge, SCM reduces the complexity of project tasks.
Improved human resource management	Maintains alignment between operational objectives, project execution procedures and human resource expectations. By identifying and exploiting personal drivers of motivation, human resources, specifically critical resources, can be motivated according to their personal interests. The importance of this should not be understated.
Strategic Outsourcing	By outsourcing carefully selected work packages, project risk can be reduced while key project team members are able to focus on their core competencies as well as the key objectives of the project as a whole.

Table 6-7: Suggested SCM Project Metrics – Adapted : (Supply Chain Council, 2008)

Metric	Description
1. Order Fulfilment Cycle Time	The average time to fulfil a customer's order from receiving an order to delivery to a customer.
2. Cash-to-Cash Cycle Time	The time it takes for an investment made to flow back into a company after it has been spent for raw materials. For services, this represents the time from the point where a company pays for the resources consumed in the performance of a service to the time that the company received payment from the customer for those services.
3. Return on Working Capital	Return on working capital is a measurement which assesses the magnitude of investment relative to a company's working capital position versus the revenue generated from a supply chain. Components include accounts receivable, accounts payable, inventory, supply chain revenue, cost of goods sold and supply chain management costs.
4. Return on Supply Chain Fixed Assets	Return on Supply Chain Fixed Assets measures the return an organization receives on its invested capital in supply chain fixed assets. This includes the fixed assets used in Plan, Source, Make, Deliver, and Return.
5. Build Cycle Time	The time associated with managing and performing the build process of a certain item
6. Source Cycle Time	Average time associated with the sourcing process
7. Cost to Build	The cost associated with managing and performing the build process of a certain item
8. Material Transportation Cost	The cost of transportation of physical material between supply chain nodes or to and from the construction site
9. Cost to Source	The cost of managing ordering, receiving and warehousing of materials and services
10. Cost to Serve	The cost associated with delivering a product or service to the final customer including both direct and indirect costs
11. Energy Cost per Unit	
12. Deliver Cycle Time	Average time associated with the delivery process of materials and resources to site
13. Inventory Days of Supply (WIP)	The amount of stock on hand, expressed in days
14. Number of Movements of Construction Materials	The total number of movements of construction material encountered on a construction site. Only movements of concerned material type is considered. Transfers, of incoming deliveries, from unload area and transportation from inventory to mounting location, is not considered.

Chapter 7. Conclusion and Recommendations

In this chapter the dominant topics from *Chapter 5* and *Chapter 6* and the research findings of this study have been summarised. A proposed list of project metrics for the construction industry is presented, based on the requirements and challenges outlined and discussed in *Chapter 5* and Chapter *6*.

The final section of the chapter has been dedicated to recommendations for proposed future research in relation to the topic of this study.

7.1 Research Findings

7.1.1 SCM - A substitute for conventional project management

The first objective of this study (*a*) was to identify SCM methodologies that are applicable to management of construction projects.

During the inception of this study, it was anticipated that there may exist certain processes or tasks that lend themselves to a specific management style or existing manufacturing methodology such as *Just-in-Time* (JIT), *Lean Construction*, Last Planner Systems (LPS) and *Theory of Constraints* (TOC). For instance, when dealing with in-situ slab construction, JIT manufacturing principles would best manage such a task but when scheduling bulk earthworks, TOC would be the ideal management style. From literature presented in *Chapter 2*, it is clear that there are numerous initiatives that have been implemented to try improve construction supply chain performance that are related to SCM methodologies. Such initiatives have yet to be wholeheartedly implemented although empirical results suggest that SCM methodologies are compatible with construction and the process of project management.

The value in SCM initiatives is in the manner in which SCM methodologies constantly monitor market and resource metrics in order to align demand planning and schedules with the objectives of a project in order to reduce the cost of production/construction. This is supported by strategically managing suppliers, collaborating with stakeholders and adopting cutting-edge software solutions throughout the project lifecycle.

The reality, however, based on the extensive literature study that was conducted during this study and coupled with the feedback received from on-site personnel and project management professionals regarding such direct applications of manufacturing theory to construction, is that such a direct and rudimental application of theory is not possible. Such a cross-industry application would require extensive reengineering of the existing management process, to the extent that the majority of the theory that makes a certain principle effective in manufacturing will be lost during the adaptation of the principle to the complexities of construction. This is an empirically founded understanding of the relationship between SCM and project management.

More broad-based management theory such as that which is prevalent in manufacturing was discussed in relation to construction. Conclusions and recommendations relating to observations made throughout the study are summarised below;

The second objective of the study (b) was to evaluate project management effectiveness. A core focus of the study was on conventional project management that is currently implemented as a project management framework throughout the vast majority of construction projects in South Africa. Conventional project management is based on the Project Management Book of Knowledge (PMBOK), a formalised reference tool for project management that is recognised as the global standard for project management. This was regarded as the first major body of knowledge as illustrated in Figure 3-5.

PMBOK is an extremely comprehensive, constantly updated document that incorporates the most current knowledge and practices of project management. However, globally, 63% of projects experience schedule delays and 49% of projects exceed their budgets and based on this premise, this study investigated what is the best way to manage a construction project. As such, alternative approaches to project management were investigated, with specific focus in Supply Chain Management (SCM).

As such, the study investigated the possibility of implementations of manufacturing management methodologies and techniques within the construction context. Through the results of a thorough literature study there appears to be a need for the implementation of a structured and formalised model such as SCOR or BSCOR in large corporations. However, it should be concluded that a SCM approach to project management in large corporations such as *Company A*, although necessary, has yet to be realised.

Project management using the SCOR model

A SCOR approach to complete project management within a construction project is not unrealistic nor is it impossible, but the drawbacks to such an implementation far outweigh the benefits that could potentially be realised through such an implementation. In conclusion, the SCOR model cannot be deemed as a suitable alternative to project management in managing a construction project, the model is simply not specific enough for implementation in the construction industry.

The reasons for the failure of SCOR and SCM within the large-corporate company environment are listed below.

1. There is a lack of complete executive buy-in that stifles SCM initiative even before they have the chance to be tried, tested, refined and implemented.

2. The complexity and speed required in SCM decision making processes is out of the reach of large structured corporate companies as they have rigid decision criteria that is cumbersome and withdrawn.

3. The sophisticated collaboration and coordination between stakeholders that is required for successful SCM implementation has yet to become a primary focus in the construction industry due to existing systems such as outsourcing, in-house management and stakeholder autonomism.

4. Large corporates realise the potential that lies in SCM implementations but don't implement structured frameworks such as SCOR as they feel that they do not have the required key resources or supply chain expertise to achieve a meaningful management-paradigm-shift across the entirety of the company's operations.

5. Any Supply Chain initiative is seen as a procurement or logistics project and is not associated with management, further-less as a project management tool.

6. The common management misconception of a "cheapest first" approach to procurement, contractor appointment and staffing. Hidden costs and additional management complexities arise from such approaches that ultimately suffocates SCM principles and leads to higher end-of-project total costs.

7. Companies do not see the value in applying an entirely new approach to project management, but rather feel that further investment in PMBOK initiatives is necessary and is more cost effective than an entirely novel approach to project management.

8. There is an overwhelming negativity surrounding SCOR and BSCOR within industry that results in a negative stigma with regards to any SCM orientated changes, founded on nothing more than human nature.

In order to successfully implement manufacturing principles such as modularisation (prefabrication) or TOC in the construction industry, specific consideration has to be made with regard to the affects that such changes to conventional construction processes may have on engineering design, coordination, site logistics and project planning.

Although there is no doubt that manufacturing methodologies such as TOC, modularisation and off-site construction result in superior quality construction and leads to improved schedule and budget adherence, such initiatives require coordinated foreword planning as well as increased design detail at early stages in the project, each of which need to be managed correctly in order to ensure project success. Each additional project-specific requirement adds a level of complexity to the on-site management and logistics of a project and if not managed correctly, can result in serious delays and budget overruns.

Failure of conventional project management practice

It was thus established that corporate companies such as Company A, who are historically the trail-blazers of new approaches to management, cannot afford to implement such radical management paradigm shifts. Through empirical observation, further research into the matter and analysis of a case study, the rationalisation of the findings of the study were validated, with the conclusion ultimately being that the adoption of manufacturing management principles in large corporations is impractical and too complicated due to the fragmented management structures and processes employed in such companies. Such large companies are simply not in a position organisationally, to implement a completely novel framework such as SCOR. For this reason, SCOR cannot be applied in place of conventional PMBOK project management, at least not in South Africa. This forms the first conclusion of this study.

Why then, is PMBOK not being implemented correctly? According to the vast majority of literature, there is nothing fundamentally incorrect with the PMBOK approach to project management, in fact, the contrary holds true. PMBOK represents the most up-to-date cutting-edge project management processes and best practices that exist in the realm of project management. The comprehensiveness of the PMBOK methodology is essentially the fundamental problem with conventional project management, specifically in a developing economy. It is the enormous complexity of the PMBOK management methodology that limits its successful implementation in the construction industry, specifically in South Africa. This addresses the third objective (c) of the study; to identify factors that cause budget overruns and schedule delays in the construction industry.

In South Africa, there are many reasons that contribute to the failure of conventional project management, listed below are a few of the main reasons discussed in Chapters 5 and 6.

1. Poor project planning
2. There is not enough time and money invested in human resource motivation
3. Scope creep and scope changes have a dramatic effect on the performance of projects
4. Poor communication and project team collaboration
5. Estimate accuracy
6. Multitasking and micro-managing
7. Inadequate risk management and change management
8. Poor selection and appointment of project managers
9. Inadequate monitoring and controlling measures (metrics) in place
10. Not understanding stakeholder requirements
11. Turnover of key resources

Since neither structured frameworks derived from manufacturing nor PMBOK management techniques are capable of achieving regular project success in large companies, it is possible that a simplification of the concept of project management itself is necessary to achieve project success in the South African context.

A hybrid approach to managing construction projects for SME's

Based on the findings of this research, a radical change in the way that projects are managed is not the solution to project management challenges that are faced by the construction industry. Is there, however, a so-called "hybrid management technique" that is founded on PMBOK principles and supplemented by various SCM philosophies and methodologies? This addresses the fourth objective (d) of the study; to identify an effective and sustainable project management strategy, applicable to project-based organisations.

The premise of this research maintains that SCM is a viable and practical alternative to project management, if not exclusively, then in a secondary role, supplementary to PMBOK project management.

SCM but more specifically, the SCOR model, was concluded to be too complicated for implementation in large companies in section 6.3.1. Grounded on this evidence, a simplification of SCM and manufacturing frameworks such as SCOR is required before attempts to implement such industry specific methodologies in project management are made. Furthermore, based on the findings of the case study at *Company A* with regard to fragmented management structures, internal procedures and executive buy-in, it is proposed that SCM may be more beneficial and more applicable to project management strategies of smaller companies.

Therefore a reduced, more simplistic management model is proposed as a possible solution to the project management challenges faced by the South African construction industry, specifically in the Small and Medium Enterprise (SME) sector. Smaller companies think they are capable of successfully managing a project or subcontracted work package, however, this is more the exception than the rule based on evidence presented both in literature and in section 4.3. As such, it is proposed that there is in fact an application for a hybrid management technique, founded on the principles of PMBOK project management and supplemented by SCM methodology and thinking.

Since, by their very definition, SME's are small businesses, where the failure of a project has dire consequences, thus the importance of ensuring projects are successful and managed correctly cannot be overlooked. However, SME's often lack the resources to appoint specialised project managers or to invest in costly software packages and instead base their approach to management on experience and intuition. SME's manage projects without any formal PMBOK project management methodology or processes. The costs associated with facilitating complete PMBOK project management are significant and the processes and best practices are extremely complex to implement and manage.

Based on this evidence, it is proposed that a hybrid model of SCM and PMBOK be implemented as an approach to managing projects, by means of conventional PMBOK implementation as well as measurement and control of a select few KPI's and critical success factors originating from manufacturing. A simplified approach to project management has the potential to be especially effective when there is pressure to appoint BBBEE contractors who might not have the same experience as established contractors or when on-the-job skills development and training is a government requirement. In such a scenario, it is the opinion of the author of this study that a simplified approach is the only way to realise effective management of such a project whilst accounting for the specific requirements of the South African construction industry.

Solutions that are applicable to SME's need to be quick, relevant and practical in nature and not necessarily based on formal project management principles. As such, SME project management requirements form the perfect platform from which to implement a hybrid management theory.

As was concluded in previous sections, there exists is no single solution that is applicable to all projects but rather there potentially exist a set of metrics that are critical to all construction projects regardless of size or complexity that are able to reduce both the complexity and workload involved in managing projects. It should be noted that each project is unique and thus additional metrics should be identified and implemented to account for this on each individual project. This forms the second conclusion of this study.

The null hypothesis (Ho) of the study; "A SCM approach to project management will improve the cost effectiveness and timeliness as well as allow for sustainable project management of a construction project, as opposed to conventional project management approaches", should be rejected based on the evidence presented in this study.

7.2 Final Conclusion and Recommendations

The aim of this study was to assess whether a SCM approach to project management, such as SCOR, could improve the cost effectiveness and timeliness of a construction project while maintaining sustainable project management control, compared to conventional project management approaches.

It was concluded that neither a complete SCM approach nor a hybrid management approach, incorporating both PMBOK and SCM principles, can be successfully implemented as a feasible alternative to PMBOK project management within a large corporate organisations, such as *Company A*. Although SCM offers various extremely powerful management tools that could potentially improve the management of construction projects, a SCM approach to management of a project is currently not feasible.

SCM frameworks such as the SCOR model, which was a focus of this study, are simply too industry specific to be directly implemented in the construction industry. The various unique peculiarities that exist in every construction project, coupled with the high degree of fragmentation that is as a consequence of the prevalence of sub-contracting, results in a project that is complex in nature. Such complexity requires implementation of complex management structures and does not lend itself exploitation of the potential benefit that structured frameworks such as SCOR have to offer.

Construction projects, in South Africa are subject to unique challenges that the vast majority of projects globally are not. The widespread implementation of transformation initiatives, preferential procurement policies, demographic employment ratios and turbulent strike action are just a few of the unique challenges that are faced by the South African industry. It must be noted that project management as per the PMBOK is first and foremost a philosophy of management and a set of guidelines rather than an elaborate set of tools and techniques.

Conventional PMBOK management guidelines are not tailored to deal with such overpowering political, economic and social factors. It should also be stated that PMBOK was initially developed for management of projects in first-world countries, not in developing or third world countries and as such, does not consider all the challenges faced by projects in developing and third-world economies. Through the research process and more specifically, through the case study conducted in this study, it was apparent that conventional approaches to the management of such factors, such as the guidelines of PMBOK, are not effective. As such, when a project is faced with such extreme political, economic and social factors, an alternative approach to project management, more specifically the schedule, needs to be adopted.

Critical Chain Project Management should be implemented in such situations as this philosophy protects the end date of a project by means of a time buffer that is comprised of safety time to account for the effects that political, economic and social factors have on project execution.

It was found that, conventional project management as per the guidelines of PMBOK, is not implemented correctly in many projects. A combination of poor communication, low skills levels and insufficient planning are among the main reasons why project management fails, however, the complete list of reasons are discussed in *section 6.1.* The findings of this study suggest that rectifying the inadequacies of conventional project management practice is far more practical than an attempt to adopt a completely novel approach to management. It is recommended, as a supplement to PMBOK, that Building Information Modelling (BIM) be integrated into project planning and execution. Resource loaded schedules are highlighted as being a necessity on any construction project. A resource loaded schedule should be a contractual requirement in all large projects as well as appointment of dedicated schedulers and planners in the pre-planning phase of such a project. By introducing these few recommendations, the principles of PMBOK can be more easily implemented, monitored and managed which ultimately should result in improved control of schedule and budget adherence. Such an approach to managing projects in large corporations should be an improvement on conventional project management, although, there is no one-approach-fits-all solution to project management.

Small and Medium Enterprises (SME's) are not subject to the same degree of fragmentation and management complexity that large corporations are and as a result, could benefit from a completely novel approach to project management. SME's are commonly subcontracted in the construction industry and as such, play a pivotal role in ensuring projects are completed within time and budget. Since SME's don't have the resources to implement project management as per the PMBOK guidelines, formal project management is often not practiced. In an effort to improve the project management process, it was concluded that a set of project metrics need to be identified. This addresses the fifth and final objective (e) of the study; to compare, based on empirical measurement, SCM and project management performance measures and metrics related to the construction industry and identify a set of critical project metrics.

Suggested project management metrics for the South African construction industry

The underlying principle behind metric measurement is control. Without being able to measure a certain metric, comparison cannot be made with benchmark industry performance and thus performance cannot be established. "You can't manage what you can't measure" (Goldratt, 1997).

Project metrics need to be specific to construction as well as being directly linked to established structured frameworks such as SCOR and BSCOR. By identifying established metrics, project management procedures benefit from existing metric definitions and management structures. Management philosophies and metrics that are implemented in manufacturing can be adapted to be applicable to the construction industry. Additionally, the use of industry benchmarking that is provided by frameworks such as SCOR and BSCOR facilitate simplification of project management processes of SME's.

The culmination of this study is a list of suggested project metrics that will serve as the basis of a hybrid management framework. Measurement of these metrics is expected to facilitate effective project control and improve the process of project management. These metrics are presented in Table 7-1. This serves as the final conclusion of this study.

Table 7-1: Suggested Hybrid Project Management Performance Metrics

Attribute	Management Metric	
Cost	Co.1.	Cost to Serve
	Co.2.	Earned Value (EV)
	Co.3.	Cost to Source
	Co.4.	Present Cost
	Co.5.	Present Value (PV)
	Co.6.	Estimate at Complete (EAC)
	Co.7.	Cash Flow
	Co.8.	Budget Critical Tasks
	Co.9.	Cash-to-Cash Cycle Time
	Co.10.	Return on Working Capital
	Co.11.	Return on Supply Chain Fixed Assets
	Co.12.	Cost to Build
	Co.13.	Over Budget Tasks
Schedule	Sc.1.	Schedule Variance (SV)
	Sc.2.	Activity Complete Percentage
	Sc.3.	Order Fulfilment Cycle Time
	Sc.4.	Build Cycle Time
	Sc.5.	Schedule Remaining
	Sc.6.	Milestones
	Sc.7.	Deliver Cycle Time
	Sc.8.	Schedule Performance Index (SPI)
	Sc.9.	Overdue Tasks
Resources	Re.1.	Response time
	Re.2.	Capacity
	Re.3.	Material Transportation Cost
	Re.4.	Source Cycle Time
	Re.5.	Resource availability
	Re.6.	Energy Cost per Unit
	Re.7.	Over allocated Resources
	Re.8.	Inventory Days of Supply (WIP)
	Re.9.	Idle Time
Project Execution	Pe.1.	Scope Change Requests
	Pe.2.	Scope Change Approvals
	Pe.3.	Number of Movements of Construction Materials
	Pe.4.	Rework
	Pe.5.	Staff Turnover
	Pe.6.	BBBEE Ratio
	Pe.7.	Induction/Approval Process Time

In summation, conventional practice of project management as per the PMBOK guidelines is an essential tool in the management of projects and is an extremely comprehensive document that should not be disregarded. However, for SME's in the South African context, PMBOK project management requires simplification. Simplification of the PMBOK management guidelines through the implementation of instances of SCM theory provides a simplified tool for use in managing projects, particularly within SME's operating in the South African construction industry.

Such an innovative "hybrid approach" to project management provides a degree of flexibility, simplicity and versatility not found in conventional project management systems that account for specific variables that are unique to the South African construction industry. It is thus imperative that the management of construction projects is reviewed and improved through alternative approaches to project management. The suggested approach involves explicit measurement and monitoring of certain critical project metrics such as those listed in Table 7-1 while disregarding other conventional project management metrics in order to focus management efforts to critical areas of application.

Without project management innovation, the management of construction projects will continue to be poor, with regular unexplained and uncontrolled budget and schedule overruns occurring. In the words of *Albert Einstein*, "Insanity is doing the same thing over and over again and expecting different results".

7.3 Future Research

The purpose of this study was simply to evaluate the possibility and scope for an alternative approach to managing projects. Based on empirical evidence, the results and findings of this study warrant future in-depth research into the feasibility of a hybrid management theory. Further case studies should be conducted in the construction project environment to identify a set of project attributes that exist in a project that lends itself to SCM. Suggested future research is outlined below.

Firstly, a simplified management framework that is applicable to SME's operating under the constraints of the South African construction industry needs to be developed fully. From the findings of this study it was determined that PMBOK is too complex for companies to implement correctly or effectively and pure-SCM is too industry specific to be applicable in the construction industry.

Secondly, the relationships, interdependencies and information flow between the main contractor, consultants, client, subcontractors and project team needs to be mapped in order to grasp the true complexity involved with managing a project. Once the interactions between these stakeholders has been clearly identified, a suitable approach to better manage the interactions and information flow between project stakeholders can be identified and validated.

Thirdly, an investigation into the willingness of suppliers and other project stakeholders to collaborate during a project needs to be ascertained. Without buy-in from all stakeholders, true SCM effectiveness cannot be realised. Feedback of the specific requirements of each stakeholder should be considered when developing the hybrid management framework.

Fourthly, the industry-wide adoption of SCM in prefabrication facilities should be investigated as the first step in developing SCM project management. Prefabrication is the aspect of construction most similar to manufacturing and as such should be a starting point for SCM implementation in the construction industry. Following which, an industry validation, based on observation of a practical implementation of a hybrid project management theory needs to be conducted in a South African construction project in order to validate the legitimacy of the proposed hybrid approach to project management.

Further investigation with regard to which metrics are critical to project success needs to be revised and explored further. Once complete, the BSCOR model needs to be re-evaluated in order to validate the merits of such a framework in the South African environment and compare the list of project metrics presented in this study with those outlined in the BSCOR model framework. Lastly, the future of human resource management needs to be investigated. Human resources are not all motivated purely by money, intrinsic motivation and a sense of wellbeing and autonomism has become a serious motivator for human resources. Furthermore, human resources are no longer loyal to a single company, preferring to amass a portfolio of experience across a broad range of fields, opting to operate as autonomous consultants instead of being employed in a conventional so-called nine-to-five job.

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Chapter 9. Appendices

9.1 Appendix A: The Builders' Supply Chain Reference Model

bAM.1.4

Number of Movements of Construction Material

The total number of movements of construction material encountered on a construction site. Only movements of concerned material type is considered. Transfers, of incoming deliveries, from unload-area and transportation from inventory to mounting location, is not considered.

Qualitative Relationship Description

A material type is to be concerned if:

- It is placed on pallet
- It is heavy
- It is a high-value material

A material is considered moved if:

- It is not transferred from unloading area to inventory
- It is not transported from inventory to mounting location.

Quantitative Relationship (optional, if calculable)

None Identified

Calculation

[Total number of movements of concerned material type]

Data Collection

Data for the components that are used to drive the calculation of Number of Movements of Construction Material are primarily associated with the construction-production processes (cBX.X, cBY.X, cBZ.X).

Discussion

Raison d'être of the Number of Movements of Construction Material metric emerged from the fact that inadequate planning in sources of construction material and construction-production results in a increased level of construction material on-site. A decreased number of "movements of construction material" is most likely to result in an increased value-added/non-value-added time ration; which derives from the notion that less time is spent by the craftsmen on moving construction material, and more time is spent on value-added activities such as mounting.

More material than needed could often be ordered to site, to attain a certain discount; however, this often results in a higher level of inventory. If the construction site is limited in space, difficulties in mounting due to the lack of free space could exist. This results in an increased number of movements. Inadequate production planning, and planning of subcontractors, could result in an increased number of movements; because the material have to be moved in a short time to a new mounting location.

bRL.2.5

% of Notify in Time

Percentage of orders which delivery time is notified to the customer within committed time

Qualitative Relationship Description

An order is considered "notified in time" if:

- The delivery time is actually notified by the supplier (or transporter)
- The time of notification is within mutually agreed tolerance
- The customer is notified if the actual delivery time is endured to a delay

Quantitative Relationship (optional, if calculable)

None Identified

Calculation

[Total number of orders notified in time] / [Total number of orders delivered] x 100 %

Data Collection

Data for the components that are used to drive the calculation of % of Notify in Time are primarily associated with the original order processing step of 'Reserve Inventory and Determine Delivery Date' (sD1.3, sD2.3 & sD3.3), and the satisfaction of that commitment through the shipment and customer receiving processes (sD1.12, sD1.13, sD2.12, sD2.13, sD3.12 & sD3.13).

Discussion

Notification times are based on original commitments agreed to by the customer. The acceptable window for notification on time should be defined in the customers' service level agreement. Orders cancelled by the customer are excluded from the metric. Order changes initiated by the customer and agreed to by the supplier supersede original commitments and form a new comparative basis for the metric. The original commitment time can refer to a range, rather than a strict time, that is acceptable to the customer (e.g. advanced shipment). This metric has no "in Full" element, such that partial deliveries can still be considered as meeting the % of Notify in Time so long as all metric criteria are met. Measuring the frequency of accepting the customer's original request time, vs. commit time, can be an important measure of customer satisfaction. The metric is most interesting in situations when a dedicated reception resource organisation doesn't exist. E.g. in larger urban construction projects, where a better reception handling tends to exist, the notify in time metric is superfluous.

Several SCOR diagnostic metrics exist that can be used to focus notification improvement efforts. Some of these include:

- Customer Commit Date Achievement Time Customer Receiving
- Delivery Location Accuracy

Orders may not be notified to the Customer Commit Time due to breakdowns in the order fulfilment and shipment process (e.g. Transportation availability). Orders may also be notified late due to carrier delivery performance / issues. In those cases when a central / external notification system is used, late notification could be caused by a system breakdown.

bB6

Build Contractor

The process of developing, designing, validating, and ultimately using a building. The process to produce a building object based on the requirements of a specific customer. In general the Build process requires that work instructions may need to be defined or refined and a site layout may need to be added and modified.

Performance Attributes	Metrics
Supply Chain Reliability	Yield
Supply Chain Responsiveness	Order Fulfillment Cycle Time, Build Cycle Time
Supply Chain Agility	Upside Build Adaptability, Downside Build Adaptability, Upside Build Flexibility
Supply Chain Costs	Cost to Build, Cost of Goods Sold
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Inventory Days of Supply (WIP), Return on Supply Chain Fixed Assets Number of Movements of Construction Materials
Best Practices	**Description/Definition**
Lean Construction	
Building Information Modelling	
Last Planner	
Line of Balance	

bP6

Plan Source Contractor

The development and establishment of courses of action over specified time periods that represents a projected appropriation of material resources of the main contractors to meet supply chain requirements.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Plan Source Cycle Time, Order Fulfillment Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Cost to Plan Source
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Return on Supply Chain Fixed Assets
Best Practices	**Description/Definition**
Building Information Modelling	
Last Planner	
Line of Balance	

bP7

Plan Source Subcontractor

The development and establishment of courses of action over specified time periods that represents a projected appropriation of material resources of the subcontractors to meet supply chain requirements.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Plan Source Cycle Time, Order Fulfillment Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Cost to Plan Source
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Return on Supply Chain Fixed Assets
Best Practices	**Description/Definition**
Building Information Modelling	
Last Planner	
Line of Balance	

bP8

Balance Sourcing Plans

The development and establishment of courses of action over specified time periods that represents a projected appropriation of material resources balanced between contractors to meet supply chain and projected requirements.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Plan Source Cycle Time, Order Fulfillment Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Cost to Plan Source
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Return on Supply Chain Fixed Assets
Best Practices	**Description/Definition**
Building Information Modelling	
Last Planner	
Line of Balance	

bP9

Plan Build Contractor

The development and establishment of courses of action over specified time periods that represents a projected appropriation of production resources of the main contractor to meet production requirements.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Order Fulfillment Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Energy Cost per Unit, Energy consumption
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Return on Supply Chain Fixed Assets
Best Practices	**Description/Definition**
Building Information Modelling	
Last Planner	
Line of Balance	

bP10

Plan Build Subcontractor

The development and establishment of courses of action over specified time periods that represents a projected appropriation of production resources of the subcontractors to meet production requirements.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Order Fulfillment Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Energy Cost per Unit, Energy consumption
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Return on Supply Chain Fixed Assets
Best Practices	**Description/Definition**
Building Information Modelling	
Last Planner	
Line of Balance	

bP11

Balance Production Plans

The development and establishment of courses of action over specified time periods that represents a projected appropriation and balance of production plans between contractors to meet production requirements.

Performance Attributes	**Metrics**
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Order Fulfillment Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Energy Cost per Unit, Energy consumption
Supply Chain Asset Management	Cash-To-Cash Cycle Time, Return on Working Capital, Return on Supply Chain Fixed Assets
Best Practices	**Description/Definition**
Building Information Modelling	
Last Planner	
Line of Balance	

bS6

Source Construction Materials

The processes of identifying and selecting sources of supply, negotiating, validating, scheduling, ordering and receiving construction materials that are parts, assemblies or specialized products that are designed, ordered and/or built based on the requirements or specifications of a specific construction project.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Order Fulfillment Cycle Time, Source Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Cost to Source, Product Acquisition Costs
Supply Chain Asset Management	Return on Supply Chain Fixed Assets, Return on Working Capital, Inventory Days of Supply (Raw Material)
Best Practices	**Description/Definition**
Goods reception	

bS7

Source Resources

The processes of identifying and selecting sources of supply, negotiating, validating, scheduling, ordering and receiving construction resources that are parts, assemblies or specialized products or services that are designed, ordered and/or built based on the requirements or specifications of a specific construction project.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Order Fulfillment Cycle Time, Source Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Cost to Source, Product Acquisition Costs
Supply Chain Asset Management	Return on Supply Chain Fixed Assets, Return on Working Capital, Inventory Days of Supply (Raw Material)
Best Practices	**Description/Definition**

bS8

Source Subcontractors' Materials

The processes of identifying and selecting sources of supply, negotiating, validating, scheduling, ordering and receiving subcontractor resources that are parts, assemblies or specialized products or services that are designed, ordered and/or built based on the requirements or specifications of a specific construction project.

Performance Attributes	Metrics
Supply Chain Reliability	None Identified
Supply Chain Responsiveness	Order Fulfillment Cycle Time, Source Cycle Time
Supply Chain Agility	None Identified
Supply Chain Costs	Cost to Source, Product Acquisition Costs
Supply Chain Asset Management	Return on Supply Chain Fixed Assets, Return on Working Capital, Inventory Days of Supply (Raw Material)
Best Practices	**Description/Definition**
Goods reception	Use a goods reception function for incoming materials

9.2 Appendix B: Expert Validation Questionnaires

Respondent 1
Position: Junior Site Engineer
Company: South African Marine Construction Company

Proposed Metric	Respondent Summary				
	Applicable to construction Project Management ?	Able to Measure such a metric in construction?	Is this a Top 5 Metric Choice?	Is this a metric that is currently being measured?	Will improve the monitoring of cost and schedule?
1. Order Fulfilment Cycle Time	Y	X	X	X	X
2. Build Cycle Time	Y	X			X
3. Source Cycle Time	Y - Normally need items urgently. Have buyers in the company that source this	X		X	X
4. Plan Source Cycle Time					
5. Make cycle time	We call this Lead Time from Supplier - Important	X		X	X
6. Deliver cycle time	Obviously Y	X	X	X	X
7. Perfect order fulfilment	Obviously Y	X		X	X
8. Yield (Output/Input Ratio)	Obviously Y	X		X	X
9. Downside supply chain adaptability					
10. Downside build Adaptability,					
11. Overall value at risk	Unsure	X			X
12. Upside build Adaptability,					
13. Upside supply chain adaptability	Unsure				

14. Upside supply chain flexibility	Unsure				
15. Upside Build Flexibility	Unsure				
16. Cost to Build	Yes	X	X	X	X
17. Material Transportation Cost	Yes	X		X	X
18. Cost to Source,	Yes	X		X	X
19. Cost to Serve	YES	X	X	X	X
20. Product Acquisition Costs	Yes	X		X	X
21. Sourcing labour Cost	Yes	X		X	X
22. Energy Cost per Unit	Yes	X		X	X
23. Energy consumption	Diesel Consumpti on Yes	X		X	X
24. Sourcing Property, Plant and Equipment Cost	Yes	X		X	X
25. Cost to Plan Source					
26. Cash-to-Cash cycle time	N	X			X
27. Inventory Days of Supply (Raw Material)	Yes	X			X
28. Return on working capital					
29. Inventory Days of Supply (WIP)					
30. Number of Movements of Construction Materials	Yes – Double handling big NO NO	X	X	X	X
31. Return on Supply Chain Fixed Assets,	Yes – Sell plant after project	X		X	X

Respondent 2

Position: Senior Project Manager

Company: Stellenbosch University

Proposed Metric	Respondent Summary				
	Applicable to construction Project Management ?	Able to Measure such a metric in construction?	Is this a Top 5 Metric Choice?	Is this a metric that is currently being measured?	Will improve the monitoring of cost and schedule?
1. Order Fulfilment Cycle Time	X	X		X	X
2. Build Cycle Time	X	X			X
3. Source Cycle Time	X	X			X
4. Plan Source Cycle Time					
5. Make cycle time	X	X	X	X	X
6. Deliver cycle time	X	X			X
7. Perfect order fulfilment	X	X			X
8. Yield (Output/Input Ratio)	X	X		X	X
9. Downside supply chain adaptability	X	X			X
10. Downside build Adaptability,	X	X			X
11. Overall value at risk	X	X			X
12. Upside build Adaptability,					
13. Upside supply chain adaptability					
14. Upside supply chain flexibility					
15. Upside Build Flexibility					
16. Cost to Build	X	X	X	X	X
17. Material Transportation Cost	X	X		X	X
18. Cost to Source,	X	X		X	X
19. Cost to Serve	X	X	X	X	X
20. Product Acquisition Costs					
21. Sourcing labour Cost	X	X			X
22. Energy Cost per Unit					

23. Energy consumption	X	X			X
24. Sourcing Property, Plant and Equipment Cost	X	X		X	X
25. Cost to Plan Source					
26. Cash-to-Cash cycle time	X	X	X	X	X
27. Inventory Days of Supply (Raw Material)	X	X		X	X
28. Return on working capital	X	X	X	X	X
29. Inventory Days of Supply (WIP)	X	X			X
30. Number of Movements of Construction Materials	X				X
31. Return on Supply Chain Fixed Assets,	X				

Respondent 3

Position: Company Director

Company: Prefabrication Producer and Supplier

Proposed Metric	Respondent Summary				
	Applicable to construction Project Management ?	Able to Measure such a metric in construction?	Is this a Top 5 Metric Choice?	Is this a metric that is currently being measured?	Will improve the monitoring of cost and schedule?
1. Order Fulfilment Cycle Time	X	X			X
2. Build Cycle Time		X			X
3. Source Cycle Time	X	X	X	X	X
4. Plan Source Cycle Time	X				
5. Make cycle time	X				
6. Deliver cycle time	X	X	X	X	X
7. Perfect order fulfilment					
8. Yield (Output/Input Ratio)	X	X			
9. Downside supply chain adaptability					

10. Downside build Adaptability,					
11. Overall value at risk					
12. Upside build Adaptability,					
13. Upside supply chain adaptability					
14. Upside supply chain flexibility					
15. Upside Build Flexibility					
16. Cost to Build	X	X			X
17. Material Transportation Cost	X	X			
18. Cost to Source,	X	X			X
19. Cost to Serve	X	X		X	X
20. Product Acquisition Costs					
21. Sourcing labour Cost					
22. Energy Cost per Unit	X	X	X	X	X
23. Energy consumption					
24. Sourcing Property, Plant and Equipment Cost					
25. Cost to Plan Source					
26. Cash-to-Cash cycle time	X	X	X		
27. Inventory Days of Supply (Raw Material)					
28. Return on working capital					
29. Inventory Days of Supply (WIP)	X	X	X	X	X
30. Number of Movements of Construction Materials	X	X			X
31. Return on supply chain fixed assets	X	X			X

Respondent 4

Position: Senior Consultant
Company: ipsoulutions

Proposed Metric	Respondent Summary				
	Applicable to construction Project Management ?	Able to Measure such a metric in construction?	Is this a Top 5 Metric Choice?	Is this a metric that is currently being measured?	Will improve the monitoring of cost and schedule?
1. Order Fulfilment Cycle Time	X	X	X	X	X
2. Build Cycle Time	X	X	X	X	X
3. Source Cycle Time	X	X		X	X
4. Plan Source Cycle Time	X	X			X
5. Make cycle time	X	X		X	X
6. Deliver cycle time	X	X		X	X
7. Perfect order fulfilment					
8. Yield (Output/Input Ratio)					
9. Downside supply chain adaptability	X	X			X
10. Downside build Adaptability,					
11. Overall value at risk					
12. Upside build Adaptability,					
13. Upside supply chain adaptability					
14. Upside supply chain flexibility	X	X			X
15. Upside Build Flexibility					
16. Cost to Build	X	X	X		X
17. Material Transportation Cost					
18. Cost to Source,	X	X			X
19. Cost to Serve					
20. Product Acquisition Costs					

21. Sourcing labour Cost					
22. Energy Cost per Unit	X	X			X
23. Energy consumption					
24. Sourcing Property, Plant and Equipment Cost	X	X			X
25. Cost to Plan Source					
26. Cash-to-Cash cycle time					
27. Inventory Days of Supply (Raw Material)	X	X	**X**	X	X
28. Return on working capital	X	X		X	X
29. Inventory Days of Supply (WIP)	X	X	**X**	X	X
30. Number of Movements of Construction Materials					
31. Return on Supply Chain Fixed Assets,					

Respondent 5

Position: Senior Design Engineer

Company: Privately Owned Engineering Consultant

Proposed Metric	Respondent Summary				
	Applicable to construction Project Management ?	Able to Measure such a metric in construction?	Is this a Top 5 Metric Choice?	Is this a metric that is currently being measured?	Will improve the monitoring of cost and schedule?
1. Order Fulfilment Cycle Time	X	X	X	X	X
2. Build Cycle Time	X	X	X		X
3. Source Cycle Time	X	X			X
4. Plan Source Cycle Time					X
5. Make cycle time	X	X		X	X
6. Deliver cycle time	X	X			X
7. Perfect order fulfilment	X	X			X

8. Yield (Output/Input Ratio)	X	X			X
9. Downside supply chain adaptability					X
10. Downside build Adaptability,					X
11. Overall value at risk	X	X			X
12. Upside build Adaptability,					X
13. Upside supply chain adaptability					X
14. Upside supply chain flexibility					X
15. Upside Build Flexibility					X
16. Cost to Build	X	X	X		X
17. Material Transportation Cost	X	X			X
18. Cost to Source,	X	X			X
19. Cost to Serve					X
20. Product Acquisition Costs	X	X			X
21. Sourcing labour Cost	X	X			X
22. Energy Cost per Unit	X	X			X
23. Energy consumption	X	X			X
24. Sourcing Property, Plant and Equipment Cost	X	X			X
25. Cost to Plan Source					X
26. Cash-to-Cash cycle time	X	X	XX	X	X
27. Inventory Days of Supply (Raw Material)					X
28. Return on working capital					X
29. Inventory Days of Supply (WIP)	X	X	X	X	X
30. Number of Movements of Construction Materials	X	X			X
31. Return on Supply Chain Fixed Assets,	X	X		X	X